Chapter 3F. Affected Environment and Environmental Consequences - Fishery Resources

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SUMMARY

This chapter summarizes the life histories and habitat needs of chinook salmon, striped bass, American shad, delta smelt, Sacramento splittail, and longfin smelt and analyzes the potential for impacts of DW project operations on these species and their habitats. Effects on these species encompass the range of potential responses of Delta fish species to DW project operations.

DW project operations and facilities under Alternative 1, 2, or 3 could cause or contribute to significant impacts on fish population abundance. These impacts would be avoided or reduced to less-than-significant levels, however, through implementation of appropriate management actions, monitoring of DW project operations, and operation of the DW project according to specified operations objectives. The following significant potential impacts were identified:

- *Construction of DW project facilities could degrade spawning and rearing habitat, which could reduce the localized reproductive success of delta smelt, Sacramento splittail, and other Delta species.*
- *Discharge of water from the DW reservoir islands to adjacent channels could increase channel water temperature, which could reduce juvenile chinook salmon survival.*
- *DW project operations could affect flows during the peak out-migration period of Mokelumne and San Joaquin River chinook salmon, indirectly increasing chinook salmon mortality.*
- *DW project operations could reduce transport flows and increase entrainment loss, which could reduce the survival of striped bass eggs and larvae; delta smelt larvae; and, possibly, longfin smelt larvae.*
- *DW project diversions could indirectly increase entrainment losses during November-January, reducing survival of juvenile striped bass and delta smelt.*

Impact avoidance and mitigation measures were developed to protect individual species and, when possible, to implement an ecosystem-based approach to sustain habitat conditions protective of multiple species and life stages throughout the Bay-Delta estuary. Implementing construction guidelines and replacing altered spawning and rearing habitat would compensate for potential fish habitat loss. Scheduling DW project discharges so they will not result in adverse water temperature changes in the Delta channels would avoid significant adverse temperature impacts on chinook salmon and other species. Proposed integration of monitoring of fish populations and flow conditions with operations criteria for diversion and discharge would reduce DW project effects related to entrainment and transport to less-than-significant levels. Use of efficient fish screens, in combination with the proposed operations criteria, would reduce entrainment loss effects to less-than-significant levels.

Implementation of Alternative 1, 2, or 3 would also result in the following less-than-significant impacts: a change in the area of optimal salinity habitat in the Delta, a potential increase in accidental spills of fuel and other materials at boat docks at the DW project islands, and an increase in entrainment loss of juvenile American shad and other species.

Effects on fish species and their habitats under the No-Project Alternative would not differ measurably from effects of current agricultural operations on the DW project islands.

INTRODUCTION

This chapter assesses impacts of DW project operations and facilities on fish species that reside in the Delta, Suisun Bay, and San Francisco Bay for at least part of their lives. The effects of DW project operations and facilities on habitat conditions common to multiple species and life stages are identified. Factors affecting the population abundance and distribution of individual species are evaluated in detail. Available information was used to identify relationships between species and their habitat.

More than 100 fish species are found in the Delta and Bay, and about 40 of these species are found in the Delta (Table F1-1 in Appendix F1, "Supplemental Information on the Affected Environment for Fisheries"). The impact assessment is limited to species that support important sport and commercial fisheries; species that are unique to the Bay-Delta environment; species that may be in danger of extinction; and species that, when considered as a group, encompass the range of potential responses to the effects of Delta water project operations and facility construction. The species included in this impact assessment are chinook salmon (*Oncorhynchus tshawytscha*), striped bass (*Morone saxatalis*), American shad (*Alosa sapidissima*), delta smelt (*Hypomesus transpacificus*), Sacramento splittail (*Pogonichthys macrolepidotus*), and longfin smelt (*Spirinchus thaleichthys*).

On-island fishery resources were not included in the fishery impact assessment. The existing on-island fishery resources are negligible relative to total fishery resources in the Delta. Existing fish populations on the DW project islands are limited to perennial ponds and drainage ditches. The ponds support introduced sunfish, catfish, and minnows primarily. No fish species that are federally listed as threatened or endangered or that are candidates for listing are known to exist on the project islands.

The discussion of fisheries in this chapter includes some terms that may not be familiar to all readers. The following are definitions of these terms as they are used in this EIR/EIS:

- **Entrapment zone**. An area or zone of the Bay-Delta estuary where riverine current meets upstream-flowing estuarine currents and variations in flow interact with particle settling to trap particles. The entrapment zone generally corresponds to a surface salinity range of 2-10 mS/cm specific conductance) (Kimmerer 1992).

- **X2**. The location in the Bay-Delta estuary relative to the Golden Gate Bridge (measured in kilometers) of the 2-ppt isohaline 1 meter off the bottom (San Francisco Estuary Project 1993). An isohaline is a line connecting all points of equal salinity.

- **Midwater trawl index**. The annual index is the sum of the weighted catch of four monthly samples (September-December) from numerous locations in the Delta and Suisun Bay. The index is assumed to be a measure of abundance when considered in relation to the catch for all other years of the sampling record (1967-1995). In the Bay-Delta estuary, the index has been developed for striped bass, American shad, delta smelt, Sacramento splittail, longfin smelt, and other species.

- **Entrainment**. The process in which fish are drawn into water diversion facilities along with water drawn from a channel or other water body by siphons and/or pumps. Entrainment loss includes all fish not salvaged (i.e., eggs, larvae, juveniles, and adults that pass through the fish screens, are impinged on the fish screens, or are eaten by predators).

- **Salvage**. Removal of fish from screens on diversion structures and the subsequent return of the fish to the water body. Fish eggs and larvae (e.g., delta smelt, striped bass, and longfin smelt) are small and pass through the screens. They are not included in salvage numbers.

- **Direct effects**. Mortality of fish attributable to DW diversions, including entrainment in DW diversions and losses resulting from changes in habitat.

- **Indirect effects**. Mortality of fish attributable to other diversions that results from DW effects on Delta flow conditions.

AFFECTED ENVIRONMENT

This section provides an overview of the life histories of selected Delta fish species and factors affecting their population abundance. More detailed information is provided in Appendix F1, "Supplemental Information on the Affected Environment for Fisheries".

Sources of Information

The assessment of potential effects of DW project operations on the habitat and populations of fish species in the Bay-Delta estuary is based on literature review, contacts with appropriate agency experts, analysis of the effects of simulated DW project operations on simulated Delta fish transport patterns, and analysis of other available data.

Ongoing studies and analyses of the Bay-Delta served as important sources of information for this assessment. Recent studies and reports include the San Francisco Estuary Project (1993), Bay-Delta hearings and workshops sponsored by SWRCB, and evaluations of effects of SWP and CVP operations on two federally listed endangered species, winter-run chinook salmon (NMFS 1995) and delta smelt (USFWS 1995).

This chapter is also based on information presented in the following chapters and appendices:

- Chapter 3A, "Water Supply and Water Project Operations", describes Delta conditions related to water supply, provides an overview of historical Delta water supply conditions, and discusses possible impacts of the DW project on Delta and California water supply.
- Appendix A3, "DeltaSOS simulations of the Delta Wetlands Project Alternatives", presents detailed results of DeltaSOS simulations of operations of the DW project alternatives and the No-Project Alternative and describes the use of DWRSIM simulation results as initial water budget terms for DeltaSOS modeling. The analysis of impacts on fishery resources described in this chapter is based on these DeltaSOS simulation results showing estimated changes in channel flows, outflow, and exports that would be associated with operations of each of the DW project alternatives and the No-Project Alternative under a range of hydrologic conditions.
- Appendix A4, "Possible Effects of Daily Delta Conditions on Delta Wetlands Project Operations and Impact Assessments", compares daily hydrologic conditions with monthly average conditions in the Delta and discusses potential differences between impact assessment based on monthly average hydrologic conditions and impact assessment based on actual daily hydrology.
- Chapter 3B, "Hydrodynamics", describes Delta hydrodynamic conditions, identifies Delta hydrodynamic variables that could be affected by operation of the DW project, and presents the results of simulations to determine DW project effects on those key variables. Effects of maximum DW diversions and discharges on local and net channel flows are analyzed.
- Chapter 3C, "Water Quality", describes key water quality variables and objectives associated with maintaining beneficial uses of Delta waters, existing Delta water quality conditions, and impacts of the DW project on water quality in Delta channels.
- Appendix F1, "Supplemental Information on the Affected Environment for Fisheries", provides additional background information on fish species included in the impact assessment.
- Appendix F2, "Biological Assessment: Impacts of the Delta Wetlands Project on Fish Species", provides background information and presents a detailed assessment of impacts of the DW project on fish species that are listed as endangered or threatened or that are candidates for future listing. Appendix F2 includes a detailed description of the models used to assess impacts.

The reader is directed to these chapters and appendices for a more detailed explanation of analytical methods and assumptions integrated into the fishery impact assessment.

Chinook Salmon

The chinook salmon is an important fish species supporting valuable commercial and sport fisheries (Allen and Hassler 1986). The Sacramento-San Joaquin River system supports four runs of chinook salmon: fall, late fall, winter, and spring. Separation of the runs is defined by the timing of upstream migration of adults.

The population abundance of all four runs of chinook salmon has declined relative to historical levels (Appendix F1, "Supplemental Information on the Affected Environment for Fisheries"). A detailed discussion of the winter-run chinook salmon, currently listed as endangered under the California and federal Endangered Species Acts, is provided in Appendix F2, "Biological

Assessment: Impacts of the Delta Wetlands Project on Fish Species".

Life History

Adult chinook salmon 2-7 years old migrate from the ocean to spawn in the upstream reaches of the major tributaries to the Sacramento and San Joaquin Rivers. Eggs are deposited in gravel nests and fry emerge after incubating for about 3 months. Juvenile salmon migrate from upstream spawning areas to downstream habitats and to the ocean.

The Delta serves as an immigration path and holding area for adult chinook salmon returning to their natal rivers to spawn. Sacramento River chinook salmon migrate primarily up the mainstem Sacramento River, but some fish use the distributaries of the Mokelumne River and enter the Sacramento River through Georgiana Slough or the DCC (Figure 1-2 in Chapter 1, "Introduction"). San Joaquin River chinook salmon migrate primarily up the mainstem San Joaquin River.

Emigrating juvenile chinook salmon are found in the Delta and Bay throughout the year, but primarily from about October through June (Figure 3F-1). Migration along the fastest and most direct migration route generally results in the highest survival of chinook salmon migrating to the ocean through the Delta.

Factors Affecting Abundance

Factors associated with the historical decline of chinook salmon populations are deleterious water temperatures in spawning and rearing habitat and blockage of adult passage to suitable spawning and rearing areas. Other factors that may affect population abundance include diversion of juveniles off the primary migration path through the Delta, entrainment of juveniles in diversions, predation during juvenile migration, toxic discharge to the rivers, and ocean fishing.

Temperature is a primary factor influencing the survival of chinook salmon in the Delta, especially during May and June (Kjelson et al. 1989a). Survival of juvenile fall-run chinook salmon during migration though the Delta appears to decline when water temperature exceeds 60°F (Kjelson et al. 1989b, USFWS 1992). The relationship between temperature and chinook salmon survival is discussed in detail in Appendix F2.

The most direct routes upstream through the Delta during adult migration to spawning areas are the Sacramento River and San Joaquin River channels. When export rates exceed San Joaquin River inflow, water in the central and south Delta consists primarily of Sacramento River water moved across the Delta by the DCC and Georgiana Slough or pulled by reverse flow through the lower San Joaquin River. Chinook salmon may become confused and their migration may be delayed, possibly resulting in reduced adult survival and fecundity.

Although the most direct route through the Delta for juvenile Sacramento River chinook salmon is the Sacramento River channel, juveniles may be drawn along an alternate route through the DCC and Georgiana Slough (Figure 1-2 in Chapter 1), where migration is delayed and losses to diversions and predation may increase. The division of Sacramento River flow at the DCC and the number of out-migrant juveniles drawn into the DCC depend primarily on DCC gate position and Sacramento River flow volume. USFWS and DFG (1987) found that when the proportion of Sacramento River flow drawn into the DCC and Georgiana Slough was high (greater than 60%) and the DCC gates were open, survival was about 50% lower for juvenile fall-run chinook salmon released above the DCC than for juveniles released below Georgiana Slough. When the DCC gates were closed, only Georgiana Slough drew water out of the Sacramento River, and survival was similar for the two release locations.

Similarly, mortality of juvenile chinook salmon diverted from the San Joaquin River into upper Old River may be greater than that of juveniles migrating down the mainstem San Joaquin River (USFWS 1993a). Entrainment in diversions (agricultural diversions and CVP and SWP exports) also increases juvenile mortality. Entrainment loss to all Delta diversions may exceed several hundred thousand juvenile chinook salmon, including substantial numbers lost to predation (DFG 1992a).

Striped Bass

Striped bass are large predatory fish introduced to the Bay-Delta estuary in about 1880. Adult striped bass live in the ocean and Bay (most may remain in the Bay) and migrate upstream to the Delta and Sacramento River to spawn (DFG 1987a). Striped bass support a large sport fishery in the Delta and Bay.

Life History

About 55% of the adult striped bass population spawn in the Sacramento River upstream of the Delta during May and June, and about 45% spawn in the San Joaquin River between Antioch and Venice Island during April and May (DFG 1987a). Percentages vary from year to year.

Semibuoyant eggs are broadcast-spawned by striped bass in open water and eggs hatch in about 2 days (DFG 1987a). Eggs and newly hatched larvae drift with the current, and Sacramento River eggs or larvae generally reach the Delta within a few days. Newly hatched larvae are carried downstream to the upstream edge of the entrapment zone.

Factors Affecting Abundance

Year-class abundance of striped bass is assumed to depend on the environmental conditions experienced by the eggs and young fish. An important factor affecting striped bass abundance may be the location of X2 (abundance is highest when outflow is sufficient to locate the 2-ppt isohaline in Suisun Bay during April-July). Other primary factors influencing young striped bass abundance are entrainment of eggs, larvae, and juveniles in Delta diversions (DFG 1992a) and discharge of toxic materials into rivers tributary to the Delta and into the estuary. Additionally, declines in the availability of major prey organisms and competition with introduced exotic fish and invertebrate species may adversely affect striped bass abundance (DFG 1992b).

X2 is a function of Delta outflow volume; as outflow increases, X2 is reduced (the 2-ppt isohaline moves downstream). Although dependent on the natural hydrology of the Sacramento-San Joaquin River system, the timing and volume of Delta outflow have been substantially modified by changes in system characteristics (i.e., channelization and flood control projects) and by operations of water project facilities (i.e., reservoirs and diversions) (Herbold et al. 1992). In general, water projects have increased summer and fall outflow and reduced winter and spring outflow (Herbold et al. 1992).

When X2 is in Suisun Bay, the proportion of the juvenile striped bass population in the Delta is lower than when X2 is in the Delta (Figure 3F-2) (DFG 1992b). The highest survival of young-of-year striped bass occurs during high-flow periods when most of the juvenile population is distributed downstream of the Delta.

Young bass are more vulnerable to entrainment in diversions when they are located in the Delta. Significant egg, larval, and juvenile mortality results annually from entrainment in SWP and CVP exports and other Delta diversions, exceeding millions of fish each year (DFG 1992a). The timing of striped bass entrainment in SWP and CVP exports is shown in Figure 3F-3. Net reverse flow in the lower San Joaquin River and in Old and Middle Rivers transports striped bass eggs and larvae toward the SWP and CVP export facilities and may increase entrainment loss.

American Shad

The American shad is the largest member of the herring family and may reach a weight of over 5 kg (Facey and Van Den Avyle 1986). American shad were introduced to the Bay-Delta estuary during the late 1800s and currently support a sport fishery.

Life History

Adult American shad immigrate to fresh water from the ocean and the Bay during March, April, and May. The primary spawning grounds are in the upper Sacramento River and its tributaries. The northern Delta and the northern portion of Old River have also supported shad spawning. (DFG 1987b.) During May-July, shad broadcast-spawn their eggs and sperm into the currents, where the semibuoyant eggs sink slowly and drift with the flow.

Shad spawned in the Sacramento River system generally rear in the tributary rivers downstream of the spawning area. Shad spawned in the Delta appear to rear primarily in the Delta. Most juvenile American shad emigrate from their freshwater rearing areas and pass through the Delta to estuarine and marine habitats between September and December (Stevens 1966).

Factors Affecting Abundance

American shad abundance may be affected by factors similar to those discussed for striped bass. The environmental conditions experienced by the eggs and young fish, especially river flows, are thought to be the most important conditions determining population abundance. Entrainment of young-of-year shad in water diversions from the Delta reduces juvenile survival. Ocean conditions also may be another important factor determining American shad abundance.

Hundreds of thousands of American shad larvae and juvenile fish are entrained each year at the SWP and CVP export facilities and in other Delta diversions (DFG 1987b). Shad spawned in the Delta are entrained as larvae and juveniles primarily during July-August (Figure 3F-3). Shad spawned upstream of the Delta are entrained as juveniles primarily during November and December.

Delta Smelt

The delta smelt is a small (2- to 3-inch-long), translucent, slender-bodied fish with a steely blue sheen. The delta smelt is found only in the Bay-Delta estuary (including the Delta, Suisun Bay, Suisun Marsh, and sometimes San Pablo Bay). Low abundance during 1983-1991 resulted in the delta smelt being listed as a threatened species under the California and federal Endangered Species Acts (58 FR 12854). A detailed discussion of delta smelt is provided in Appendix F2, "Biological Assessment: Impacts of the Delta Wetlands Project on Fish Species".

Life History

Delta smelt are found where salinity is generally less than 2 ppt (56 FR 50075). Delta smelt adults disperse widely into fresher water in late fall and winter as the spawning period approaches, moving as far upstream as Mossdale on the San Joaquin River and the confluence with the American River on the Sacramento River. Spawning occurs in fresh water from February through June and may peak during late April and early May (Wang 1991, Sweetnam and Stevens 1991, Stevens et al. 1990). Most adult (1-year-old) delta smelt die after spawning (56 FR 50075).

After the eggs hatch (in about 12-14 days), delta smelt larvae float to the surface and are carried by the currents (Stevens et al. 1990). Under natural outflow conditions, the larvae are carried downstream to near the upstream edge of the entrapment zone (e.g., 2-ppt salinity), where they typically remain and grow to adult size.

Factors Affecting Abundance

Year-class abundance of delta smelt depends on the environmental conditions experienced by the eggs and young fish. Factors that may adversely affect abundance of delta smelt include a decline in the availability of major food organisms, low adult population levels resulting in low reproductive success, water diversions from the Delta, reduced Delta outflow, introduced exotic species of fish and invertebrates, toxic substances, and reduced habitat resulting from channelization in the Delta and draining and filling of tidelands (Stevens et al. 1990, Moyle and Herbold 1989, Wang 1986). As with striped bass, an important determinant of smelt abundance may be the location of the population in the estuary, which determines the effect of other factors, such as entrainment in diversions.

Delta outflow affects delta smelt abundance and distribution. High outflow may transport smelt larvae and early juveniles downstream of the Delta, provide improved habitat conditions in Suisun Bay, and cause salinity conditions preferred by larval and juvenile smelt to be located downstream of the Delta and away from the effects of Delta diversions (USFWS 1994). In addition, high outflow dilutes toxic materials and increases turbidity that may reduce predation.

Delta smelt distribution is a function of outflow (Figure 3F-2). Stevens et al. (1990) showed that over 50% of the variation in the proportion of the smelt population found in Suisun Bay is explained by variation in Delta outflow. During high-flow years, the entrapment zone and the majority of delta smelt are located in Suisun Bay throughout summer and into fall (DFG 1992c). During low-flow years, the entrapment zone and the majority of delta smelt are located in the Delta.

Variability in the annual abundance of delta smelt, which is indicated by the fall midwater trawl index (see Appendix F2), may be partially explained by the number of days that X2 is located in Suisun Bay (USFWS 1994). Delta smelt abundance is greatest when X2 is located in Suisun Bay during February-June. Abundance is lowest when X2 is upstream or downstream of Suisun Bay.

Delta smelt are vulnerable to entrainment in diversions throughout their life cycle, particularly in dry years when they are concentrated in the Delta where most fresh water is diverted (DWR 1993b). The number of juvenile smelt entrained at the SWP and CVP fish facilities and in other Delta diversions has exceeded 1 million during some years. Peak entrainment losses of juveniles occur during May, June, and July (Figure 3F-3). High entrainment of larvae likely occurs during late March, April, and May. Entrainment may increase when net flows are reversed in the lower San Joaquin River and in Old and Middle Rivers. Net reverse flow increases transport of delta smelt larvae toward the SWP and CVP export facilities.

Sacramento Splittail

Sacramento splittail are large (more than 30 centimeters [cm] long) cyprinids (minnow family) endemic to the lakes and rivers of the Central Valley (Moyle et al. 1989). Sacramento splittail abundance steadily declined after 1983 and the species has been proposed for listing as threatened under the federal Endangered Species Act (59 FR 862). DFG has designated Sacramento splittail a species of special concern.

A detailed discussion of Sacramento splittail is provided in Appendix F2, "Biological Assessment: Impacts of the Delta Wetlands Project on Fish Species".

Life History

Sacramento splittail are freshwater fish capable of tolerating moderate levels of salinity (10-18 ppt) (59 FR 862). Splittail are largely confined to the Delta, Suisun Bay, Suisun Marsh, and Napa Marsh and, outside of the spawning season, are rarely found more than 5-10 miles above the upstream boundaries of the Delta (Moyle et al. 1989, Natural Heritage Institute 1992). Incidental catches of large splittail in fyke traps set by DFG in the lower Sacramento River during spring indicate that splittail migrate from Suisun Bay, the Delta, and lower river reaches to upstream spawning habitats.

Splittail spawn adhesive eggs over flooded streambanks or aquatic vegetation when water temperatures are between 9°C and 20 C (Moyle 1976, Wang 1986). Spawning has been observed to occur as early as January and to continue through July (Wang 1986). Peak spawning occurs during March through May.

Larval splittail are commonly found in the shallow, weedy areas where spawning occurs. Larvae eventually move into deeper, open-water habitats as they grow and become juveniles (Wang 1986).

Factors Affecting Abundance

Habitat modification is probably the major factor contributing to the decline of splittail (DFG 1992d). Dams, diversions, pollution, and agricultural development have eliminated or altered splittail habitat. Year-class survival is affected by Delta outflow, possibly because spawning success depends on spawning habitat availability (Moyle et al. 1989). The storage of water in upstream reservoirs and diversions reduces the frequency and magnitude of floodflows, thereby affecting the availability of flooded vegetation during the spawning season. Additionally, entrainment in diversions reduces survival of adult and juvenile fish.

The fall midwater trawl index of splittail abundance is positively correlated with Delta outflow during March-May (Appendix F2), indicating that variability in abundance is at least partially explained by flow. Because spawning and early rearing of larval splittail are associated with shallow vegetated areas, inundation of riparian and seasonally flooded habitats may be an important factor determining year-class success. River flow determines the availability of shallow-water habitats with submerged vegetation during late winter and spring (Daniels and Moyle 1983).

Upstream water storage facilities and water diversions have changed the seasonal magnitude and duration of flows to upstream habitats and to the Delta. Reduced duration of flooding may degrade conditions necessary for spawning and larval development. Spawning habitat may be dewatered before larvae have moved to channels that provide permanent rearing conditions.

Thousands of splittail juveniles and adults are entrained in agricultural diversions and exports at the CVP and SWP pumping facilities. Juvenile splittail are salvaged at the state and federal fish protection facilities primarily during May-July (Figure 3F-3). Juveniles from the current year's spawn first appear in salvage during April. Substantial numbers of small juveniles (i.e., less than 30 millimeters [mm] long) and larvae may also be entrained (but not salvaged), but entrainment of larvae and early juveniles depends on the proximity of spawning habitat to a given diversion.

Longfin Smelt

Longfin smelt is a 3- to 6-inch-long silvery fish that is endemic to the Bay-Delta estuary and other estuaries along the Pacific Coast north of San Francisco Bay. Longfin smelt were the most abundant smelt species in the estuary prior to 1984 and have been commercially harvested (Wang 1986).

A detailed discussion of longfin smelt is provided in Appendix F2, "Biological Assessment: Impacts of the Delta Wetlands Project on Fish Species".

Life History

Except when spawning, longfin smelt are most abundant in Suisun and San Pablo Bays, where salinity generally ranges between 2 ppt and 20 ppt (Natural Heritage Institute 1992). Longfin smelt migrate upstream to the Delta and spawn in fresh water primarily during February through April (Natural Heritage Institute 1992). The eggs are adhesive and are probably deposited on rocks or aquatic plants.

Eggs hatch in 37-47 days at 45°F. Larval abundance in the Bay-Delta estuary peaks during February-April. (DFG 1992e.) Shortly after hatching, a longfin smelt larva develops a gas bladder that allows it to remain near the water surface (Wang 1991). Larvae are swept downstream into nursery areas in the western Delta and Suisun and San Pablo Bays (DFG 1987c, Baxter pers. comm.).

Factors Affecting Abundance

Year-class abundance of longfin smelt appears to depend on the environmental conditions experienced by the eggs and young fish. An important factor affecting longfin smelt abundance is Delta outflow during their larval and early juvenile life stages. Outflow affects the downstream distribution of smelt and their vulnerability to entrainment in diversions. Population abundance is highest following high outflow during winter and early spring.

The fall midwater trawl index of juvenile abundance is positively related to Delta outflow (Appendix F2). Regression analysis of the abundance index on outflow has indicated that 79% of the index variability is explained by changes in January and February Delta outflow. (Stevens and Miller 1983; DFG 1987c, 1992e.)

Entrainment of longfin smelt by Delta diversions affects spawning adults, larvae, and early juveniles. Older juveniles and prespawning adults generally inhabit areas downstream of the Delta. In normal and wetter years, longfin smelt larvae and young juveniles are transported out of the Delta quickly, except during periods of low Delta outflow, and therefore are unlikely to be entrained in diversions. During the 1987-1992 drought, many juveniles remained in the Delta and were salvaged at the state and federal fish protection facilities during April-June (Figure 3F-3). Given the high salvage rates of young-of-year juveniles in some years, many longfin smelt larvae also are likely entrained, especially during February, March, and April.

Other Fish Species

Although many other fish species reside in the Bay-Delta estuary, potential effects of DW project operations are not assessed for these species individually because their responses to potential changes in habitat conditions caused by DW project operations would be similar to those of one or more of the species life stages discussed above. Assessment of DW project impacts on these other species is therefore encompassed by the discussion of potential effects on the species listed above. Additional species include freshwater resident species (sunfish, catfish, and minnows), steelhead trout (*Oncorhynchus mykiss*), green and white sturgeon (*Acipenser medirostris* and *A. sapidissima*), and numerous Bay species. Because of the possibility that steelhead trout may be listed in the future under the federal Endangered Species Act, this species is discussed in Appendix F2, "Biological Assessment: Impacts of the Delta Wetlands Project on Fish Species".

Significant numbers of resident fish are entrained by water diversions, but the actual entrainment impact on populations cannot be determined because information on population size, screening efficiency (except for a few species), and indirect entrainment losses is unavailable. Based on movement patterns and habitat affinities, open-water pelagic fish (e.g., threadfin shad [*Dorosoma petenense*]) are probably most susceptible to entrainment in diversions, followed by bottom-feeding catfish and minnows. Sunfish have the lowest susceptibility to entrainment because of their relatively small home ranges and associations with cover.

Factors affecting abundance of steelhead trout are similar to those for chinook salmon. In the Sacramento-San Joaquin River system, most steelhead are found in the Sacramento River and its tributaries and are subject to factors affecting Sacramento River chinook salmon.

Young sturgeon survival is probably affected by entrainment in diversions, toxics, and prey availability. Salvage at the SWP fish screens totals about 3,000 fish annually. Flows upstream of the Delta have more effect than Delta outflow on sturgeon spawning success.

The number of Bay fish species greatly exceeds the number of species in the Delta. Biological responses of estuarine and marine species to Delta outflow conditions are highly variable (DFG 1992e, Herrgesell et al. 1983). Some populations remain stable regardless of outflow conditions, particularly species having wide salinity and temperature ranges and a broad range of food requirements (e.g., gobies). Some marine species (e.g., anchovies [*Engraulis mordax*]) may become locally more abundant if salinity increases in response to decreased Delta outflow. Higher Delta outflow may directly or indirectly cause broader dispersal of estuarine species, decreasing intraspecific and interspecific competition (Stevens and Miller 1983). Higher outflow may increase recruitment of marine species into the Bay, provide more habitat for estuarine species, and increase food availability.

Invertebrate Species

Responses of populations of aquatic invertebrate species to potential changes in habitat conditions resulting from DW project operations would be encompassed by the responses of one or more of the fish species life stages discussed in detail above. For example, the response of Bay shrimp (*Crangon franciscorum*) to outflow is similar to the response shown by longfin smelt (i.e., abundance increases at higher outflow).

The distribution and abundance of benthic invertebrates (those living on or in the bottom substrates) respond to changes in habitat availability, largely determined by the location of the salinity gradient, which is a function of Delta outflow. The more stable salinity regime of the interior Delta appears to provide favorable habitat for permanent persistence of a greater species diversity of benthic populations. Greater variability of benthic densities in the western Delta and Suisun Bay is caused by periodic large freshwater outflows and salinity changes. Under dry conditions (e.g., 1976 and 1977), numbers of *Corophium* (an amphipod) decreased in the western Delta, allowing temporary colonization by saltwater-adapted species (Markmann 1986).

Effects of Delta outflow, Delta flow patterns, and diversions on planktonic invertebrates (invertebrates living suspended in the water column) are similar to the effects discussed above for planktonic life stages of striped bass, American shad, delta smelt, and longfin smelt.

Neomysis, a mysid shrimp, is probably the single most important zooplankton species in the diet of Delta and Suisun Bay fish. Some of the annual fluctuations in abundance of this organism and shifts of population distribution between Suisun Bay and the Delta can be attributed to variations in Delta outflow. The highest *Neomysis* densities are observed between salinity of 1.2 ppt and 2.6 ppt (Knutson and Orsi 1983). *Neomysis* has been abundant in only two years since 1977, both characterized by high spring outflow that located the entrapment zone downstream of the Delta (DFG 1987d). Location of the entrapment zone in the Delta reduces both the habitat area available to *Neomysis* and the density of *Neomysis* prey (i.e., phytoplankton and zooplankton) (Orsi and Knutson 1979, Arthur and Ball 1980). Location in the Delta also increases vulnerability to entrainment in Delta diversions.

Populations of the copepod *Eurytemora affinis* have recently declined, possibly reflecting changes in the Delta environment attributable to introduction of competitive and predatory species, reduced Delta outflow, and increased diversions.

IMPACT ASSESSMENT METHODOLOGY

The primary fishery-related effects of DW project facilities and operations would be changes in Delta flows. Water quality, local habitat conditions, and entrainment of fish and invertebrates in diversions could also be affected by DW project operations and facilities.

Simulations of DW Project Operations

Assessment of DW project effects on Delta fish species and their habitat involves predicting fish and habitat responses to changes in Delta conditions that could result from DW project operations. DW diversions, storage, and discharges and estimated changes in channel flows, outflow, and exports were simulated for DW project operations under a range of hydrologic conditions (see Chapter 3A, "Water Supply and Water Project Operations"). Changes in these factors were estimated by comparison of operations under each DW project alternative with operations under the No-Project Alternative. The results of these DW project simulations, in combination with information on fish behavior and habitat needs, provided the basis of the fishery impact analysis described in the following section, "Analytical Approach and Impact Mechanisms", which estimated potential effects of DW project operations on habitat conditions, fish transport, and fish entrainment in Delta facilities.

Models Used and General Modeling Assumptions

The simulations used to estimate DW project effects were performed with DeltaSOS, the monthly Delta operations model developed by JSA to evaluate Delta flow effects of specified Delta water management operations, such as DW's proposed project, with the new Delta standards. As described in Appendix A2, "DeltaSOS: Delta Standards and Operations Simulation Model", DeltaSOS simulates operations of a project (diversions, storage, and discharges) based on the 70-year (1922-1991) hydrologic record according to a specified set of assumptions regarding facilities, demand for exports, and Delta standards.

The historical (1922-1991) record of Delta diversions, flows, and water quality provides basic data for evaluating effects of water project operations and facilities on hydrologic conditions. Although this hydrologic record serves as an estimate of likely future hydrologic conditions, it does not provide an accurate estimate of future Delta conditions. Historical data do not represent conditions that would occur with existing reservoirs and diversion facilities, under the current operations criteria, with applicable Bay-Delta standards, and for the existing levels of demand (including municipal, agricultural, industrial, and fish and wildlife needs) for surface water from the Sacramento-San Joaquin River system. Appropriate modeling of future Delta project operations must be based on current and anticipated regulatory standards, facilities, and demand for exports, rather than those conditions that existed during the years of the hydrologic record.

These current conditions are represented in the initial Delta water budget used for the DeltaSOS simulations, which consists of results of DWR's SWP operations planning model DWRSIM. DWR uses DWRSIM to simulate monthly water project operations (e.g., channel flows, exports, and outflow) that would occur under existing conditions and standards, based on the range of hydrologic conditions represented by the hydrologic record for the Delta for 1922-1991. The results of DWRSIM 1995-C6B-SWRCB-409, performed in January 1995, were provided to SWRCB for use by JSA as the initial Delta water budget in these DeltaSOS simulations to evaluate proposed DW project impacts. These DWRSIM results were used by SWRCB to describe likely Delta conditions under the objectives of the 1995 WQCP. DWR is continually refining its DWRSIM runs and used a slight modification of this January run when finalizing the 1995 WQCP. The results of these two runs have no differences that affect the DW project simulations. (The initial water budget used in DeltaSOS modeling is described in Appendix A1, "Delta Monthly Water Budgets for Operations Modeling of the Delta Wetlands Project".)

In the DWRSIM simulation, Delta operations were controlled by criteria specified by SWRCB in the 1995 WQCP. CVP and SWP operations criteria included in the biological opinions for winter-run chinook salmon and delta smelt are encompassed by and consistent with the operations criteria in the 1995 WQCP (USFWS 1995, Stern pers. comm.).

In the DeltaSOS simulations of the DW project alternatives, the CVP and SWP Delta pumping facilities were assumed to export all water that was available under existing operations criteria and existing facility capacities. That is, the DeltaSOS simulations were based on the assumptions that available water would be exported, irrespective of an actual export demand, and that south-of-Delta storage facilities (e.g., MWD's Domenigoni Reservoir) were available for any required storage of the exported water. This simulated level of export is likely representative of future conditions and the potential availability of water to diversion, storage, and discharge for export by DW. The simulation does not encompass all permutations that may occur under real DW operations for any given year. The timing, frequency, and volumes of diversions to and discharges from the DW reservoir islands will be affected by factors that cannot be simulated (factors other than availability of water and pumping capacity, such as operational decisions at the discretion of DW, DWR, Reclamation, or SWRCB or in response to Endangered Species Act considerations).

Use of the No-Project Alternative as Baseline Reference

Simulated effects of DW project operations on the Delta cannot be directly compared with the historical record of Delta operations for purposes of impact assessment because historical Delta operations did not include current operating criteria; facilities; and conditions, such as demand for exports. To provide a point of reference for assessment of impacts associated with simulated operations of the DW project, it was also necessary to simulate a baseline condition consisting of existing Delta facilities and operating criteria but without operations of the DW project. This point of reference is represented by the simulated No-Project Alternative. As described in Chapter 2, "Delta Wetlands Project Alternatives", the No-Project Alternative represents the intensified agricultural operations that would be implemented on the DW project islands if the DW project were not approved. Results of assessment of all potential impacts of the DW project represent changes that would result from DW project operations in relation to the No-Project Alternative.

Analytical Approach and Impact Mechanisms

As described above, DeltaSOS simulations (based on DWRSIM simulations of Delta flows and diversions corresponding to the 1922-1991 hydrologic record, modified by the 1995 WQCP objectives) provided the data for the evaluation of flow changes resulting from DW operations. Simulation results for total Delta diversions, DW project diversions, DW discharges for export, DCC and Georgiana Slough flows, lower San Joaquin River flow, and Delta outflow were used to determine the effects of DW project operations on fish habitat conditions and individual species entrainment or mortality. Information on the distribution and timing of fish life stages was incorporated into the evaluation of flow effects. Additionally, the impact assessment identified area and type of fish habitat that could be affected by construction activities, including additional levee improvements (i.e., riprapping) and construction of intake and discharge structures, fish screens, and boat docks.

The following discussions describe the methods used to assess effects on fish transport and movement, habitat, and entrainment. These methods are explained in detail in Appendix A, "Detailed Methodology for Using Transport, Chinook Salmon Mortality, and Estuarine Habitat Models", of Appendix F2, "Biological Assessment: Impacts of the Delta Wetlands Project on Fish Species".

Figure 3-1 in Chapter 3, "Overview of Impact Analysis Approach", provides an overview of the modeling methods described below.

Methods for Assessing Effects on Chinook Salmon

Mortality of juvenile chinook salmon could be affected by discontinuation of unscreened agricultural diversions onto the DW reservoir islands, addition of diversions to fill the reservoir islands (including the resulting reduction in outflow), export of DW discharges (i.e., changes in central Delta flows), and changes in the magnitude and timing of diversions onto the habitat islands.

Mortality indices for fall- and winter-run chinook salmon migrating through the Delta were calculated using a chinook salmon mortality model modified from a model developed by USFWS (Kjelson et al. 1989b). The mortality index should not be construed as the actual level of mortality that would occur because simulated monthly conditions cannot accurately characterize the complex conditions and variable time periods that affect survival during migration through the Delta. The mortality index provides a basis for comparing the effects of alternative DW operations on chinook salmon that could result from changes in diversions and Delta flows.

The USFWS mortality model was developed from studies of hatchery-reared juvenile fall-run chinook salmon released in the Delta during April-June. Use of the model to estimate winter-run mortality assumes applicability of the model to in-river juvenile migration during September-May.

The USFWS mortality model has two major components: mortality attributable to temperature and mortality attributable to Delta exports. The USFWS model assumed that exports affect only salmon drawn off the Sacramento River and into the DCC and Georgiana Slough and then into the Mokelumne River part of the Delta. Salmon continuing down the Sacramento River are assumed to be unaffected by exports. The effect of exports on salmon migrants from the Sacramento River is assumed to depend on the volume of Sacramento River water diverted. Exports composed primarily of San Joaquin River flow would have less effect on salmon migrants from the Sacramento River than would exports composed primarily of Sacramento River flow.

In this impact assessment, a cross-Delta flow parameter (CDFP) was substituted for export. CDFP is calculated with the DeltaMOVE fish transport model discussed below under "Methods for Assessing Effects on Fish Transport" and in Appendix F2. The model simulates introduction of a concentration of particles into the Mokelumne River side of the Delta at the beginning of a month. The Mokelumne River side of the Delta receives inflow from the DCC and Georgiana Slough, as well as inflow from the Mokelumne River. Inflow from the DCC and Georgiana Slough is usually orders of magnitude greater than Mokelumne River inflow. The proportion of the concentration entrained in exports and other Delta diversions at the end of the month is the monthly CDFP. The CDFP, the salmon mortality model, and DeltaMOVE are described in detail in Appendix A of Appendix F2.

Methods for Assessing Effects on Fish Transport

The distribution of many fish species, including striped bass and delta and longfin smelt, is affected by changes in Delta flow patterns and diversions during the larval and early juvenile life stages. Many other factors affect the distribution of larvae and juveniles in the estuary, including the distribution and timing of spawning, larval growth, and the response of fish to various environmental conditions (i.e., salinity, temperature, and prey distribution).

The fish transport model DeltaMOVE was used to simulate an entrainment index for evaluating the effects of water project operations on fish distribution and entrainment loss in the Delta (Appendix F2). Although relationships between physical and biological factors controlling larval and early juvenile distribution are complex and difficult to ascertain, the fish transport model simulations are based on the assumption that movement of water is representative of the movement of young fish. The fish transport model uses net channel flows, tidal mixing flows, channel volume, and salinity to estimate effects of Delta inflows and water project operations on distribution and entrainment loss of larval and early juvenile life stages. The effects of the DW project on the distribution and potential entrainment loss of larvae and early juvenile life stages were evaluated by comparing entrainment indices for the No-Project Alternative conditions with entrainment indices for conditions under DW project operations.

The entrainment index for Delta conditions with the DW project alternatives indicates the direction and magnitude of potential change in entrainment loss relative to conditions simulated for the No-Project Alternative. The entrainment index should not be construed as the actual level of entrainment that would occur. Simulated monthly conditions, a fixed spawning distribution, and the assumed transport characteristics of a life stage cannot accurately characterize the complex conditions and variable time periods that affect the entrainment process.

Striped bass eggs and larvae and delta and longfin smelt larvae are assumed to be transported primarily by net channel flow and tidal mixing flows. Whether fish are lost as a result of Delta diversions depends on the volume of diversions, the volume of net flow moving fish toward the diversion points, and the length of time that larvae reside in the Delta channels. Increased rate of movement out of the Delta and toward Suisun Bay results in lower losses to Delta diversions. Delta residence time is determined by the magnitude of Delta outflow; higher outflows reduce the period of residence in the Delta spawning areas and increase the proportion of the simulated population transported to Suisun Bay during a given period.

Methods for Assessing Changes in Estuarine Habitat Area

Salinity is an important habitat factor, and estuarine habitat often is defined in terms of a salinity range (Hieb and Baxter 1993). All estuarine species are assumed to have optimal salinity ranges, and different life stages within a species often vary in their salinity preferences. Species year-class production may be determined partly by the amount of rearing habitat available within the optimal salinity range.

Rearing habitat area, based on the estimated optimal salinity range, was calculated for striped bass and delta and longfin smelt. The optimal salinity range is 0.1-2.5 ppt for striped bass, 0.3-1.8 ppt for delta smelt, and 1.1-18.5 ppt for longfin smelt (Obrebski et al. 1992, Hieb and Baxter 1993).

The Bay-Delta estuary has a complex shape, and the area of optimal salinity habitat varies greatly with its location. The geographical location of the upstream and downstream limits of the optimal salinity habitat are computed from monthly average Delta outflow and the optimal salinity range of the species (Appendix F2). The surface area at different locations was estimated from nautical charts. Total area of optimal salinity habitat was computed for each month through addition of all areas contained between the upstream and downstream limits of the optimal salinity range.

The annual optimal salinity habitat area was the weighted average of all months. Details of these calculations of optimal salinity habitat are included in Appendix F2.

Methods for Assessing Direct Entrainment Loss

Direct entrainment loss is the total number of fish diverted onto the DW project islands. Also included in the direct entrainment loss estimate are fish impinged on DW project fish screens and eaten by predators exploiting habitats created by the intake facilities.

The intakes on all DW island siphons would have fish screens. Fish screen operations and design are being developed in consultation with DFG and NMFS; DW will apply the best available technology at the time of construction to obtain the highest efficiency under variable Delta conditions. For juvenile and adult fish greater than 20 mm in length, the fish screens are assumed to nearly eliminate direct entrainment losses. Losses of fish eggs and larvae and juvenile fish that cannot be effectively screened are discussed in greater detail under the respective species in the impact assessment. The screen structures would be in the water only during actual diversions (as assumed in the project description), and predator populations associated with the screens are not likely to increase during the 2- to 4-week diversion period. However, the presence of boat docks, pilings, and other structures associated with the intakes could provide habitat for predatory fish that could increase entrainment losses.

The historical (1979-1990) CVP and SWP salvage records (see Appendix F2) were used to estimate the timing and magnitude of vulnerability to entrainment for screenable-sized fish of all target species (Figure 3F-3). The information was used in conjunction with simulated estimates of the volume and timing of diversions to determine potential entrainment loss.

Daily Operations

Monthly simulations of operations (using DWRSIM and Reclamation's planning model PROSIM) are currently the best available tools for estimating Delta inflows and upstream operations. Monthly simulations provide general information on the monthly timing and volume of DW project diversions and discharges. Simulations of daily operations would provide a more accurate representation of DW project operations. Daily water project operation models, however, are not available to simulate Delta inflows and operation of upstream facilities.

The daily and monthly average flows and operations for several months of an example water year, 1981, are compared in Appendix F2, "Biological Assessment: Impacts of the Delta Wetlands Project on Fish Species". Detailed daily DW operations are discussed in Appendix A4, "Possible Effects of Daily Delta Conditions on Delta Wetlands Project Operations and Impact Assessments".

Use of simulated monthly average flows in the impact assessment provides a general indication of how the DW project would operate and how DW operations may affect Delta flows. DW operations under daily conditions could be less constrained or more constrained than DW operations under monthly average conditions. Effects on fisheries may be similarly under- or overestimated.

In general, the pattern of entrainment loss is similar for daily and average monthly hydrology (see Figure 5-2 in Appendix F2). The magnitude of the entrainment index for daily flows, however, may be substantially greater or less than the entrainment index for monthly average flows. The difference between the daily and monthly average effects indicates the importance of considering flow conditions over time increments of less than a month in developing project operations criteria. The level of DW project effects during actual operation, and actions necessary to avoid substantial adverse effects on delta smelt and other species, will depend on daily flow conditions in the Delta and on the real-time distribution of vulnerable fish life stages. Mitigation was developed to account for impacts of daily operations.

Criteria for Determining Impact Significance

Populations of fish and other aquatic organisms may be reduced because of increased mortality and changes in habitat availability and suitability that affect species survival, growth, migration, and reproduction. In general, impacts on fish populations are significant when project operations cause or contribute to substantial short- or long-term reductions in abundance and distribution. An effect is found to be significant, based on the State CEQA Guidelines, if it:

- substantially reduces the abundance or the range of a rare or threatened species;
- substantially threatens to eliminate an animal community;
- substantially causes fish habitat to drop below self-sustaining levels;
- substantially reduces fish habitat; or
- has considerable cumulative effects when viewed with past, current, and reasonably foreseeable future projects.

NEPA regulations state that the significance of an action is determined by the severity of the impact in the context of local, regional, national, and societal perspectives. Consequently, significance cannot be rigidly defined because the significance of an impact will vary with the species, population dynamics, impact mechanism, and surrounding environment.

In this impact assessment, impacts were considered significant if it was determined that conditions contributing to existing stress would be worsened by DW project operations and facilities, resulting in a substantial reduction in population abundance and distribution. The definition of a "substantial" reduction varies with each species, depending on the ability of the population to maintain or exceed current production levels through mechanisms that compensate for reduced abundance of earlier life stages. Many fish populations are resilient in the face of mortality caused by human activities and can sustain high levels of exploitation. All available data, including information on past responses of fish populations to changes in environmental conditions and direct mortality, were evaluated to assist in determining population dynamics relative to impact mechanisms.

Impacts were considered cumulatively significant if it was determined that project operations and facilities would contribute to existing or future stress that causes or would cause a substantial reduction in population abundance and distribution. Current impacts and population trends and foreseeable future project impacts were considered in the determination of cumulative impact significance.

IMPACTS AND MITIGATION MEASURES OF ALTERNATIVE 1

Alternative 1 involves potential year-round diversion and storage of water on Bacon Island and Webb Tract (reservoir islands) and management of Bouldin Island and Holland Tract (habitat islands) primarily for wetlands and wildlife habitat. Existing agricultural diversions would cease; however, water would be diverted for wetland management.

In DeltaSOS simulations of DW project operations under Alternative 1, it is assumed that diversions onto the reservoir islands could occur any time of the year when surplus flows are available (under the 1995 WQCP criteria). Water discharged from the reservoir islands is assumed to be treated as Delta inflow; export of DW discharge by the CVP and SWP Delta pumping facilities would comply with 1995 WQCP criteria for percentage of Delta inflow diverted (percent inflow) (see Chapter 3A, "Water Supply and Water Project Operations"). Discharges of water from the DW project islands would be exported in any month when unused capacity within the permitted pumping rate exists at the SWP and CVP pumps and the 1995 WQCP percent inflow limits do not prevent use of that capacity.

Water would be diverted to the reservoir islands (238-TAF water storage capacity) at a maximum average monthly diversion rate of 4,000 cfs, which would fill the two reservoir islands in one month. The maximum average daily diversion rate would be 9,000 cfs during the first day of siphoning of water onto the reservoir islands (see Chapter 2, "Delta Wetlands Project Alernatives", for more information on diversion rates during reservoir filling). The maximum average daily discharge rate would be 6,000 cfs, but the maximum monthly average discharge rate is assumed to be 4,000 cfs, a rate that would empty the two reservoir islands in one month.

Effects of DW project operations under Alternative 1 were determined through comparison of flow and habitat conditions for operations and facilities simulated by DeltaSOS with and without the DW project (i.e., under Alternative 1 and under the No-Project Alternative). The flow and salinity conditions simulated for the No-Project Alternative and Alternative 1 are presented in Chapters 3A, "Water Supply and Water Project Operations", and 3C, "Water Quality". The DeltaSOS simulations of Delta inflows and water project operations provided the basis for most of the species-specific evaluations discussed below under "Potential Species-Specific Effects".

Table 3A-7 in Chapter 3A and Tables A3-7a and A3-7b in Appendix A3, "DeltaSOS Simulations of the Delta Wetlands Project Alternatives", show the results of DeltaSOS simulations of DW reservoir island diversions and discharges under Alternative 1, based on the hydrologic record for 1922-1991. Habitat island diversions under Alternative 1 (Table 3A-2 in Chapter 3A and Table A1-8 in Appendix A1, "Delta Monthly Water Budgets for Operations Modeling of the Delta Wetlands Project") would vary little from year to year, although timing of diversions would be flexible and would depend on habitat island water management needs.

Effects of Construction Activities

Construction activities for Alternative 1 include construction of intake facilities, fish screens (for new and existing diversions), discharge facilities, and boat docks. Boat docks would be constructed in conjunction with each of the discharge and diversion facilities. Additionally, boat docks associated with recreation facilities would be constructed at other locations on the DW reservoir and habitat islands. Piles would be driven to hold the floating docks in place. (See Appendix 2, "Supplemental Description of the Delta Wetlands Project Alternatives", for details on boat docks and siphon and pump stations.) Dredging is not anticipated and exterior levee improvements will be minor. Ongoing maintenance programs for the exterior levees, however, would continue (see Chapter 3D, "Flood Control").

The intake and discharge facilities and boat docks will be situated on relatively steep, riprapped levee slopes. Dredging of levee slopes and channels is not proposed. The proposed location of the facilities is not in what is believed to be preferred spawning or rearing habitat of delta smelt and Sacramento splittail (i.e., shallow vegetated habitat).

Pilings and boat docks constructed on existing riprap add structure and increase habitat diversity. Some species (e.g., some species of sunfish) would benefit from increased habitat diversity. Predation on other species (e.g., delta smelt) may increase (see discussion under "Potential Species-Specific Effects").

If intake sites or boat docks were located in or near shallow vegetated habitat, however, spawning habitat for delta smelt, Sacramento splittail, and other Delta resident species may be lost or altered. The habitat area lost would be small relative to the total area of similar habitat in the Delta, and such loss would have minimal effects on fish populations. Loss of habitat could have a significant adverse effect on localized reproduction of delta smelt, Sacramento splittail, and resident species.

Summary of Project Impacts and Recommended Mitigation Measures

Impact F-1: Alteration of Habitat. Construction of intake facilities and fish screens, discharge facilities, and boat docks on the DW project islands could adversely change spawning and rearing habitat used by Delta fish species, resulting in habitat loss. Specific spawning habitat parameters have not been defined for delta smelt and Sacramento splittail. Shallow vegetated habitat is believed to be important for the spawning success of splittail and delta smelt (USFWS 1995). Shallow vegetated habitat is also important to the spawning and rearing success of other Delta species. Historical and ongoing activities (e.g., dredging, placement of riprap, and levee construction) have destroyed substantial areas of shallow vegetated habitat in the Delta, and recent downward trends in the population abundance of delta smelt and Sacramento splittail may indicate the need to preserve the remaining habitat. Although the loss of habitat area to DW construction activities would be small relative to the total area of similar habitat in the Delta, the impact is considered significant.

Implementing Mitigation Measure F-1 would reduce Impact F-1 to a less-than-significant level.

Mitigation Measure F-1: Implement Fish Habitat Management Actions. DW shall implement the following actions:

- **Six months before beginning construction, DW shall provide USFWS and DFG with detailed habitat maps of the intake, discharge, and boat dock sites**. The maps should show the areas that may be directly affected by construction, and should also show adjacent habitat within 200 feet of the proposed facilities. A mapped area should include the area from the center line of the levee toward the center of the adjacent channel to a depth of -10 feet mean sea level (msl). The maps should identify all physical and biological features, including substrate, depth (relative to msl), and vegetation. Habitats likely to be altered by construction of intake, discharge, and boat dock facilities should be clearly identified, and quality and quantity of each habitat type should be specified. Focus should be on habitats potentially used by Sacramento splittail, delta smelt, and other native species.

- **Prior to beginning construction, DW shall implement a fish habitat replacement plan**. The plan should identify spawning and rearing habitats that should be created or restored to replace shallow vegetated habitat permanently destroyed by construction activities. Shallow vegetated habitat should be replaced at a ratio of 3:1.

  The replacement ratio of 3:1 is consistent with habitat restoration and replacement needs identified by USFWS for other Delta projects (e.g., Formal Consultation on Effects of the Proposed Los Vaqueros Reservoir Project on Delta Smelt, September 9, 1993 [USFWS 1993b]). The replacement ratio compensates for the uncertainty of the success of habitat restoration and creation, uncertainty of suitability of the restored habitat for the target species, and the potential time lag between habitat alteration and habitat replacement.

  Replacement could be accomplished through independent actions taken by DW, participation in the SB 34 Delta Levees Project Management Program (Littrell pers. comm.), or participation in Category III actions under the 1995 WQCP and similar habitat restoration activities.

- **DW shall perform construction and maintenance activities that affect in-water habitat only during September-December, when feasible.** Best management practices should be implemented to minimize sediment disturbance and to prevent toxic substances associated with construction equipment and materials from entering the Delta channels.

Effects on Water Quality

This section addresses potential water quality effects of proposed discharges of stored water from the DW reservoir islands (Webb Tract and Bacon Island) and boat-related spills at docks on the DW islands. Effects of DW project operations on seawater intrusion (i.e., the location of X2) are discussed below under "Effects on Delta Outflow".

DW Reservoir Island Discharge

Organic Materials and Toxics. Water discharged from the DW reservoir islands is not expected to contain materials toxic to aquatic organisms. Pesticides, currently a component of Delta agricultural discharge, would be applied at reduced levels on the DW reservoir islands. Soluble toxic materials are not known to be present in the soil or water on the DW reservoir islands.

Although water discharged from the DW reservoir islands would not contain toxic materials, it may have elevated levels of DOC and particulate organic carbon (POC) (e.g., zooplankton and phytoplankton). Discharge of such additional material is expected to have minimal biological effects in the Delta and could increase availability of food for Delta fishes.

Chapter 3C, "Water Quality", contains a detailed analysis of the potential effects of the DW project on Delta water quality.

Dissolved Oxygen. When filled, the DW reservoirs would be relatively shallow (i.e., generally less than 20 feet deep) and water would be well mixed. It is assumed that DO levels in the DW reservoirs would be similar to those in the Delta channels. Algal blooms on the reservoir islands, however, may cause periodic differences between DO levels on the DW reservoir islands and in the Delta channels. With implementation of recommended mitigation, DW discharge would not be allowed to reduce DO levels in the receiving channel by more than 1 mg/l (see Chapter 3C, "Water Quality").

Water Temperature. Factors controlling the effect of DW discharges on Delta channel water temperature include initial channel water temperature, temperature of the stored water on the DW reservoir islands at the time of discharge, volume of the discharge, volume of the receiving channel, flow and mixing in the receiving channel, and meteorological conditions.

Delta channel water temperature depends primarily on meteorological conditions. During some months (September-October and March-June), water temperature may depend also on flow. Under high-flow conditions, river inflow may affect water temperature in the channels adjacent to the DW reservoir islands.

If the temperature on the DW project islands is substantially greater than water temperature in the Delta channels, DW discharges could increase channel water temperature. Increased channel water temperature could affect survival, growth, and reproduction of aquatic organisms.

If the altered channel water temperature exceeds 60°F (Kjelson et al. 1989b), chinook salmon survival could be significantly reduced. Temperatures greater than 60° may also adversely affect growth (Appendix F2). October and April-June are the months of juvenile chinook salmon migration when the temperature of DW discharge is likely to exceed 60°F and may also exceed water temperature of the receiving channel. The proportion of the juvenile population migrating during October or April-June is variable but could exceed 50% of the annual production. The proportion of the juvenile chinook salmon population exposed to DW discharge would likely be much less because most juvenile chinook salmon do not migrate along the Old and Middle River pathway (USFWS 1987).

Boat Docks

The introduction of DW project boat docks is expected to increase boat-related activities in the Delta. The boat docks would concentrate effects of minor fuel and lubricant spills from individual boat engines and other boat-related discharge at the dock locations. Fueling stations are not proposed as part of the boat docks. The relatively strong tidal currents in the channels surrounding the DW habitat and reservoir islands would disperse spills quickly. Boat docks located adjacent to spawning and early rearing areas of Sacramento splittail, delta smelt, and resident species could have localized, less-than-signfiicant adverse impacts.

Summary of Project Impacts and Recommended Mitigation Measures

Impact F-2: Increase in Temperature-Related Mortality of Juvenile Chinook Salmon. Meteorological conditions may result in water temperature on the DW reservoir islands being greater than water temperature in the adjacent Delta channels. Discharge of stored DW water could increase channel water temperature. The water quality objective for the Delta states that "the natural receiving water temperature of intrastate waters shall not be altered unless it can be demonstrated to the satisfaction of the Regional Board that such alteration in temperature does not adversely affect beneficial uses" (SWRCB 1991). Water temperatures greater than 60°F may adversely affect juvenile chinook salmon survival. If water temperature in the Delta channels exceeds 60°F, an increase in channel water temperature greater than 1°F would have a significant adverse impact on juvenile chinook salmon survival.

Implementing Mitigation Measure F-2 would reduce Impact F-2 to a less-than-significant level.

Mitigation Measure F-2: Monitor the Water Temperature of DW Discharges and Reduce DW Discharges to Avoid Producing Any Increase in Channel Temperature Greater Than 1°F. DW shall monitor water temperature at appropriate time intervals in DW discharge siphons and in the receiving channels. Monitoring would be required during October-June whenever DW project water is discharged.

The volume and timing of discharge from the DW reservoir islands should be adjusted to avoid any calculated increase in channel water temperature greater than 1°F. The need for monitoring and the methodology for calculation of channel water temperature changes attributable to DW project discharge will be determined through consultation with SWRCB and the Regional Water Quality Control Board. Details will be included in the terms and conditions developed by SWRCB for the DW project.

To be consistent with the water quality objectives for the estuary and the Sacramento River at Freeport, the temperature of the discharged water may not be more than 5°F warmer than the receiving water temperature (SWRCB 1991). When the receiving water temperature is greater than 66°F during October-June, the temperature of the discharged water must be less than or equal to the temperature of the receiving water.

Impact F-3: Potential Increase in Accidental Spills of Fuel and Other Materials. Accidental spills of fuel and other materials related to recreational boat use would be concentrated at DW boat dock locations. Such spills could occur adjacent to spawning and early rearing areas of Sacramento splittail, delta smelt, and other Delta species. Because spills would have localized effects, are random, and are not an occurrence of normal project operations, this impact is considered less than significant (also see Chapter 3C, "Water Quality").

Mitigation. No mitigation is required.

Potential Flow and General Habitat Effects

This section discusses potential general effects on fish habitat, transport, and entrainment that could result from implementing Alternative 1. The discussion covers the following:

- effects of DW project diversions on outflow and salinity and, therefore, on habitat availability;
- effects of DW project diversions and discharges on Delta channel flow patterns, which affect fish transport to suitable habitat and to pumping facilities where they may be vulnerable to entrainment; and
- effects of DW project diversions and discharges on percentage of Delta inflow diverted, which is associated with fish entrainment at the CVP and SWP export pumping facilities.

Effects on Delta Outflow

Delta outflow is a primary factor associated with Bay-Delta fish abundance, distribution, and habitat conditions. The effects of outflow on transport of fish larvae and juveniles are discussed below under "Potential Species-Specific Effects". Delta outflow also affects the concentration of toxic and organic materials downstream of the Delta (San Francisco Estuary Project 1993).

DW project diversions would directly reduce Delta outflow (Table 3F-1). Although the maximum average monthly DW diversion rate is 4,000 cfs, the maximum average daily DW diversion rate could reach 9,000 cfs for the first day. DW diversions would not be allowed to cause the Delta outflow objectives of the 1995 WQCP to be violated. Under Alternative 1, DW diversions were simulated to reduce average monthly outflow by more than 25% during September-January in 18 years of the

70-year simulation. For other months, no DW diversions were simulated, or simulated diversions coincided with high outflow volumes (i.e., reductions in outflow were relatively small). For simulated outflows under the No-Project Alternative and Alternative 1, see Chapter 3A, "Water Supply and Water Project Operations".

Effects on Salinity

By reducing Delta outflow, DW diversions affect salinity distribution in the estuary. The effect of reduced outflow on salinity is represented by the change in X2 (distance in kilometers of the 2-ppt isohaline from the Golden Gate Bridge). The simulations of DW project operations show that X2 would shift upstream when outflow is reduced by DW diversions.

During February-June (the critical habitat months for many estuarine species [SWRCB 1995]), DW project operations would cause upstream shifts in X2 of up to 1.4 kilometers (Table 3F-2). During September, October, and November, the simulated upstream shift in X2 would approach or exceed 3.5 kilometers in some years. The magnitude of the shift in X2 is a function of both the change in Delta outflow (caused by DW diversion) and the volume of outflow. Reductions in outflow caused by DW diversions have less effect on the location of X2 when the outflow is greater. The greatest shift in X2 occurs with diversions at low outflows, when X2 is located upstream near the confluence of the Sacramento and San Joaquin Rivers.

Although the objectives of the 1995 WQCP would be met under DW project operations, the upstream shift in X2 attributable to DW diversions could reduce the area of optimal salinity habitat in Suisun Bay and the Delta. Change in area of optimal salinity habitat in the estuary is discussed in the sections on optimal salinity habitat for individual species under "Potential Species-Specific Effects" below.

Effects on Delta Flow Patterns

Delta flow patterns potentially affect the movement of fish through the Delta, their arrival in downstream habitats, and their susceptibility to entrainment in diversions. Net flow in the Delta channels is affected by river inflows, channel geometry, location and volume of Delta diversions, and closure or removal of channel barriers.

Channel flows affecting the central Delta (i.e., the San Joaquin River from Stockton to Twitchell Island, including the most northerly parts of Old and Middle Rivers) are discussed in this section. The central Delta is the "switchyard" of the Delta. Channel flows into and out of the central Delta could affect fish movement in the Sacramento, Mokelumne, and San Joaquin Rivers. The channel flows discussed in this section include major inflows to the central Delta from the Sacramento River (i.e., the DCC and Georgiana Slough) and the San Joaquin River (at Stockton), flow between the central Delta and the western Delta (QWEST), and flows in Old and Middle Rivers.

DCC and Georgiana Slough. Diversion of Sacramento River flow through the DCC and Georgiana Slough could have detrimental effects on winter-run chinook salmon and could also affect distribution and survival of other species. Flow through the DCC and Georgiana Slough is a function of Sacramento River flow and operation of the DCC gates. DW project operations would not affect Sacramento River flow and DCC gate operation. The volume of the DCC and Georgiana Slough flow would be the same under Alternative 1 and the No-Project Alternative because exports and DW diversions would not change the DCC and Georgiana Slough flows (see Tables A3-5 and A3-8 in Appendix A3, "DeltaSOS Simulations of the Delta Wetlands Project Alternatives").

San Joaquin River at Stockton. With a barrier in Old River, nearly all San Joaquin River flow moves through the Delta past Stockton. The barrier was assumed to be in place during April-May and October for the 1922-1991 simulations. The barrier was assumed to be removed if San Joaquin River inflow exceeded 10,000 cfs.

When the Old River barrier is not in place, Old River flow is a function of San Joaquin River flow and, to a lesser extent, export at the SWP and CVP Delta pumping facilities. When the San Joaquin River flow at Vernalis exceeds 2,000 cfs, Old River flow is approximately 60% of the total San Joaquin River inflow and the flow division is unaffected by exports. For Vernalis flows less than 2,000 cfs, decreased Vernalis flow and increased exports reduce the proportion of flow toward Stockton. When total San Joaquin River inflow is about 500 cfs, flow toward Stockton is negligible or may be slightly reversed because of exports.

DW project operations under Alternative 1 would not affect total San Joaquin River inflow and Old River barrier placement. The volume of San Joaquin River flow past Stockton would be the same under Alternative 1 and the No-Project Alternative (see Tables A3-5 and A3-8 in Appendix A3).

QWEST Flow. QWEST is a calculated flow parameter representing net flow between the central Delta and the western Delta. Although QWEST criteria are not included in the 1995 WQCP, QWEST criteria have previously been considered for protection of central Delta fish (NMFS 1993). DW project diversions would directly reduce QWEST. DW discharge for export would not affect QWEST.

If QWEST under the No-Project Alternative is simulated to be positive (i.e., net flow is toward Suisun Bay), simulated DW diversions reduce the net flow volume or reverse the direction of net flow. Simulated diversions resulted in 14 reversals of net positive flow direction, primarily during September-December in DeltaSOS modeling of Alternative 1 (Tables A3-5 and A3-8 in Appendix A3). If QWEST under the No-Project Alternative is simulated to be negative (i.e., net flow is toward the central Delta), simulated DW diversions would increase the net negative flow volume by an amount equal to the DW diversion.

The effects of change in QWEST on fish species depend on flow conditions throughout the Delta and on the distribution of fish. Fish effects of DW diversions for variable QWEST flow are evaluated under "Potential Species-Specific Effects" below.

Old and Middle Rivers. In all months of the 1922-1991 simulation, net flow in Old and Middle Rivers toward the south (i.e., negative flow) averaged between 6,000 cfs and 9,000 cfs (see Tables A3-5 and A3-8 in Appendix A3). DW project diversions would increase net southerly flow in Old and Middle Rivers between Bacon Island and Webb Tract (Table 3F-3). The increase would not exceed 4,500 cfs, the maximum diversion capacity of Bacon Island. Flows to the south of Bacon Island would not be affected by DW diversions.

DW discharge for export would also increase net southerly flow in Old and Middle Rivers (Table 3F-3). Net flow would change in Old and Middle Rivers between Webb Tract and Bacon Island only when DW project water is discharged for export from Webb Tract. Discharge from Bacon Island would affect only flows south of Bacon Island. Discharge for export could increase net southerly flow by a maximum of 6,000 cfs between Bacon Island and the CVP and SWP Delta pumping facilities and a maximum of 4,000 cfs between Webb Tract and Bacon Island.

The effects of the change in net Old and Middle River flow on fish species depend on concurrent flow changes in the rest of the Delta and on the distribution of fish. More detailed analysis of effects of DW diversions and DW discharges for export are presented under "Potential Species-Specific Effects" below.

Effects on Percentage of Delta Inflow Diverted

Percentage of Delta inflow diverted was introduced in the 1995 WQCP as an export limit to reduce entrainment of various species' life stages by the major export pumps (CVP and SWP) in the south Delta. A major concern is the movement of fish toward the south Delta with water drawn from the Sacramento River. South Delta diversions (SWP, CVP, CCWD, and agricultural diversions) generally exceed the San Joaquin River inflow and draw Sacramento River water across the Delta.

In simulations of DW project operations, DW diversions were treated the same as CVP and SWP exports and were limited by the percent inflow criteria of the 1995 WQCP (i.e., during any month, the sum of DW diversions and export as a percentage of Delta inflow would not exceed the maximum allowed under the 1995 WQCP). The criteria allow export (plus DW diversion) of 35% or less of Delta inflow during February-June and 65% during July-January; export (plus DW diverions) of between 35% and 45% is allowed under the criteria during February if January runoff is less than 1.5 MAF. The simulation showed that under the 1995 WQCP, percentage of inflow diverted was allowed to exceed 35% in February in 40 of the 70 simulated years. For the No-Project Alternative and Alternative 1, there were 15 years when percentage of inflow diverted exceeded 35% in February. In DeltaSOS modeling, DW discharge for export was included in the calculation of Delta inflow. Percent inflow is calculated by dividing CVP Tracy and SWP Banks export, including export of DW discharge, by Delta inflow.

DW diversions would increase the percent inflow diverted, but operations would comply with the criteria in the 1995 WQCP. The increase in percent inflow diverted could increase entrainment of estuarine species by Delta diversions. A detailed discussion of entrainment effects of DW project operations is presented below under "Potential Species-Specific Effects".

Potential Species-Specific Effects

DW project effects on abundance of chinook salmon, striped bass, American shad, delta smelt, Sacramento splittail, and longfin smelt were determined using available species-specific models that relate species effects to habitat conditions. Species abundance indices and habitat conditions were compared for operations under the No-Project Alternative and under DW project operations. Results of the assessment of effects are described below for each of these species.

Chinook Salmon

Following are major concerns about DW project impacts on chinook salmon:

- increased water temperature from DW discharge,
- increased division of flow off the Sacramento River through the DCC and Georgiana Slough,
- increased division of flow off the San Joaquin River through Old River near Mossdale,
- reduced potential to escape the Delta because of reduced positive QWEST or increased negative QWEST, and
- increased attraction to south Delta diversions (i.e., increased southerly flow in Old and Middle Rivers).

DW effects on potential water temperature changes were discussed previously (see "Water Temperature" under "DW Reservoir Island Discharge"). DW project operations would not affect DCC and Georgiana Slough flows or Old River flow at Mossdale (see "DCC and Georgiana Slough" and "San Joaquin River at Stockton" in the previous section). DW operations would reduce the potential for juvenile chinook salmon to escape the Delta and would increase attraction to south Delta diversions.

The mortality index for chinook salmon during migration through the Delta indicates the effect on migration. The following discussions describe changes in the mortality index of juvenile chinook salmon that were estimated to result from simulated DW project operations under Alternative 1 relative to operations of the No-Project Alternative.

For the simulations of Alternative 1, it was assumed that the first available Delta water would be diverted onto the DW reservoir islands. If fish abundance is a function of flow (i.e., water availability), vulnerability to diversion effects under Alternative 1 may also be a function of flow. Migration timing of juvenile chinook salmon each year is assumed to be a function of flow and inherent run characteristics. In the simulation of mortality during migration, the model varied migration timing each year according to occurrence of storm events. For example, seaward migration of winter-run chinook salmon peaks during February and March; however, storm events (increased availability of water) can cause greater proportions of the winter-run chinook salmon population to migrate downstream to rear in the Delta (see Appendix F2, "Biological Assessment: Impacts of the Delta Wetlands Project on Fish Species"). The simulated proportion migrating each month varied by more than 30% from year to year (e.g., during February, migration percentage ranged from 13% to 53% for the 70-year simulation).

Figure 3F-4 shows the total Delta migration mortality for fall-run chinook salmon originating in the Sacramento River. The total Delta mortality index simulated for the 1922-1991 period ranges from about 14% to 75% of the annual production of fall-run juveniles entering the Delta (Table 3F-4). The change in the mortality index attributable to DW project operations simulated for Alternative 1 cannot be discerned in Figure 3F-4. The change in fall-run mortality averages about 0.03% and ranges from -0.02% to 0.20% (Table 3F-4). Reduced mortality is the result of agricultural diversions being forgone during years when the reservoir islands would not fill or discharge.

The relatively small effect of Alternative 1 operations on juvenile fall-run chinook salmon originating in the Sacramento River is attributable to the timing of fall-run migration relative to timing of DW project operations. As discussed above under "Affected Environment", juvenile fall-run out-migrate primarily during April-June; under Alternative 1, water would be diverted to storage primarily during October-February and would be discharged for export primarily during July and August.

A mortality index was not developed specifically for chinook salmon originating in the Mokelumne and San Joaquin Rivers. The effects of DW operations on survival of Mokelumne and San Joaquin River juvenile migrants, however, is potentially several times greater than the effects on survival of juvenile chinook salmon in the Sacramento River. Approximately 20%-40% of Sacramento River juvenile migrants are exposed to central Delta conditions, whereas all Mokelumne and San Joaquin River migrants move through the central Delta and are exposed to the effects of exports and south Delta diversions.

Although potentially greater than the effects of DW operations on Sacramento River juvenile migrants, the effects of DW operations on juvenile fall-run chinook salmon originating in the Mokelumne and San Joaquin Rivers would generally be small. Most juvenile out-migration occurs during April and May, but water would be diverted to storage primarily during October-February and would be discharged for export primarily during July and August. Diversions to fill the DW project islands that coincide with major periods of juvenile out-migration (e.g., in April and May) could have significant adverse effects. Discharge of DW project water to export during April and May would have adverse effects on chinook salmon, but the effects would be less than diversion effects because additional Sacramento River water would not be drawn across the Delta.

Figure 3F-5 shows the winter-run migration mortality index attributable to all Delta diversions for the 70-year simulation. The total Delta mortality index simulated for the 1922-1991 period ranges from 6% to 17% of the annual production of winter-run chinook salmon juveniles. The index is lower for winter run than for fall run because water temperature is lower during juvenile winter-run migration through the Delta. Simulated operations under Alternative 1 changed mortality relative to mortality under the No-Project Alternative by -0.02% to 0.43% (an average of 0.08%) (Table 3F-4).

DW project effects on late fall- and spring-run chinook salmon would be similar to effects described for Sacramento River fall run and winter run. Late fall-run juveniles and spring-run yearlings migrate through the Delta during fall. Peak spring-run juvenile migration precedes fall-run migration in the spring. DW diversions and discharges could occur during out-migration of the late fall and spring runs (Tables A3-7a and A3-7b in Appendix A3, "DeltaSOS Simulations of the Delta Wetlands Project Alternatives).

The increased mortality of juvenile chinook salmon includes direct DW project effects and indirect effects (i.e., mortality attributable to other Delta diversions that results from DW effects on Delta flow conditions). Mortality estimates, however, did not include the benefits of fish screens, and DW project operations with effective fish screens in place would have minimal direct adverse effects on juvenile chinook salmon mortality. DW project operations would have a small but significant indirect adverse impact on survival of chinook salmon juveniles migrating through the central Delta.

Striped Bass

DW project effects on striped bass were evaluated for transport of eggs, larvae, and early juveniles from April through June; habitat availability for larvae and early juveniles during April through July; and entrainment of larvae and juveniles throughout the year.

Transport. Operations under Alternative 1 could affect striped bass survival and abundance by affecting transport flows. The estimated percentage of the spawned population that is entrained provides an index of losses during transport to downstream optimal low-salinity habitat.

DW operations would have significant adverse effects on transport and entrainment of striped bass eggs and larvae. Figure 3F-6 shows the total annual entrainment loss of striped bass attributable to all Delta diversions for the 70-year simulation. Total Delta entrainment loss simulated for 1922-1991 ranges from about 1% to 31% of the annual production of striped bass eggs and larvae. The simulations indicate that operations under Alternative 1 could change the annual entrainment loss relative to loss under the No-Project Alternative by -0.02% to 1.5% (Table 3F-5). Reduced entrainment is the result of agricultural diversions being forgone during years when the reservoir islands would not fill or discharge. The increased entrainment index includes direct entrainment that could result from DW operation effects on Delta flow conditions under Alternative 1.

The assumed spawning distribution can have a substantial effect on the simulated entrainment index for total Delta diversions (see "Delta Smelt", below). The simulations for striped bass assumed that 55% of the population spawned upstream of the Delta in the Sacramento River and 45% spawned in the San Joaquin River. Eggs spawned in the central Delta would be more affected by exports and diversions than eggs spawned in the Sacramento River or in the lower San Joaquin River. Entrainment losses attributable to DW project operations could be much larger or smaller than the analysis indicates, depending on the actual distribution of spawn and Delta flow conditions at the time of DW diversions and discharges.

Optimal Salinity Habitat. Striped bass year-class survival may be related to optimal salinity habitat area. DW project diversions would have minor effects on striped bass habitat area. Under the No-Project Alternative and Alternative 1, the annual weighted habitat area available for striped bass during the simulated 1922-1991 period ranges from about 51 km^2 to 102 km^2 (Figure 3F-7). Change between habitat area simulated for the same year for DW project operations and for the No-Project Alternative ranged from -1.82 km^2 to 2.86 km^2 (average increase in area for the 70-year simulation of 0.18 km^2) (Table 3F-6). Increased area would result from DW agricultural diversions being forgone during May-July when the DW project does not divert.

Direct Entrainment. Potential entrainment of larvae is described above under "Transport". Operations under Alternative 1 would likely cause minimal direct entrainment of juvenile striped bass. Although the presence of juvenile striped bass (Figure 3F-3) may coincide with the timing of diversions (Table 3A-7 in Chapter 3A, "Water Supply and Water Project Operations"), juvenile striped bass would be screened from DW reservoir and habitat island diversions. Unscreened agricultural diversions would be eliminated from the DW project islands and direct entrainment (and impingement) could be reduced. However, indirect effects of diversions under Alternative 1 (e.g., effects on predation and environmental cues that determine successful migration to the Bay) could increase juvenile losses, including losses to entrainment at the SWP and CVP Delta pumps. Substantial salvage of juvenile striped bass has historically occurred at the SWP and CVP fish protection facilities during November-January (Figure 3F-3). The impact would be significant.

American Shad

DW project operations would likely have small effects on eggs and larvae of American shad. Most American shad spawn upstream of the Delta (see "Affected Environment") and larvae remain in the rivers to rear. Shad eggs and larvae spawned in the Delta could be affected by DW project operations; however, diversions are unlikely to occur under Alternative 1 during the May-July spawning period (Table 3A-7 in Chapter 3A). DW discharges for export may coincide with spawning and early rearing of American shad; however, DW discharge for export would primarily affect conditions in the central and south Delta.

Entrainment of juvenile shad in Delta diversions peaks during November and December, coinciding with downstream migration through the Delta. Substantial DW diversions may occur during November and December under Alternative 1 (Table 3A-7 in Chapter 3A). Juvenile shad would be screened from DW reservoir and habitat island diversions and project operations would likely cause minimal direct entrainment. As with striped bass, indirect effects of Alternative 1 operations (e.g., effects on predation and on environmental cues that determine successful migration to the Bay) could increase juvenile entrainment at the SWP and CVP Delta pumps. The impact is less than significant because DW diversions primarily affect central Delta conditions. Most shad juveniles migrate down the Sacramento River and would not enter the central Delta.

Delta Smelt

DW project effects on delta smelt were evaluated for transport of larvae and juveniles during February-June; habitat availability for larvae and early juveniles during February-August; and entrainment of larvae, juveniles, and adults throughout the year.

Transport. DW project operations would have a significant adverse impact on delta smelt survival and abundance by affecting transport flows. As described in the "Affected Environment" section, delta smelt spawn in freshwater channels in the Delta. After hatching, larvae may require net flow movement for transport to downstream optimal low-salinity habitat. As for striped bass, DeltaMOVE was used to simulate transport of delta smelt to downstream habitat following hatching in the Delta and to calculate an index of entrainment losses during transport.

Figure 3F-8 shows the total annual entrainment loss of delta smelt attributable to all Delta diversions for the 70-year simulation. Total Delta entrainment loss simulated for 1922-1991 ranges from 1% to more than 36% of the annual production of delta smelt larvae. The simulations indicate that operations under Alternative 1 could change the annual entrainment loss relative to loss under the No-Project Alternative by -0.02% to 3.2% (an average increase in the entrainment index of 0.62%) (Table 3F-5). The increased entrainment index includes direct entrainment in DW diversions (and export of DW discharge) and indirect entrainment that could result from DW operation effects on Delta flow conditions.

Little is currently known about factors influencing the annual variability in distribution and timing of delta smelt spawning. Hatching is assumed to take place during February-June. For the impact assessment, 50% of the total annual spawn was assumed to occur on the Sacramento River side of the Delta and 50% of the spawn was assumed to be distributed equally between the San Joaquin River, Mokelumne River, and central Delta areas (i.e., 16.66% in each area). The assumed spawning distribution can have a substantial effect on the simulated entrainment index for total Delta diversions (see Appendix F2, "Biological Assessment: Impacts of the Delta Wetlands Project on Fish Species"). Larvae hatched on the Sacramento side of the Delta are less affected by export than larvae hatched in the central Delta.

Optimal Salinity Habitat. Delta smelt year-class survival may be related to optimal salinity habitat area. DW project diversions would have minor effects on delta smelt habitat area.

Under operations of the No-Project Alternative and Alternative 1, the annual habitat area available for delta smelt during the simulated 1922-1991 period ranged from 41 km^2 to 68 km^2 (Table 3F-6). Change in habitat area under DW project operations relative to the area under the No-Project Alternative ranged from -0.91 km^2 to 1.05 km^2 (average increase in area for the 70-year simulation of 0.05 km^2) (Table 3F-6, Figure 3F-9). The relatively small increase in area occurs because of increased outflow attributable to forgone DW agricultural diversions relative to the No-Project Alternative conditions during the rearing period (February-August).

Direct Entrainment. Potential entrainment of larvae is described above under "Delta Smelt Transport". Although the presence of adult and juvenile delta smelt near DW project diversions (Figure 3F-3) may coincide with the timing of DW diversions (Table 3A-7 in Chapter 3A), older juvenile and adult delta smelt would be screened from DW reservoir and habitat island diversions.

Operations under Alternative 1 would likely have minimal adverse effects on direct entrainment of adult and older juvenile delta smelt. Unscreened agricultural diversions would be eliminated from the DW project islands and direct entrainment (and impingement) could be reduced. However, as with striped bass, indirect effects of DW project diversions could increase juvenile and adult delta smelt entrainment at the SWP and CVP Delta pumps and contribute to a significant adverse impact.

Sacramento Splittail

Construction of DW project facilities could affect localized Sacramento splittail habitat, and DW project diversions could increase splittail entrainment. Although DW project operations could have adverse effects on localized populations of splittail, the effect on overall population abundance would be minimal.

Habitat. As discussed under "Effects of Construction Activities" above, splittail spawning and rearing habitat could be affected near proposed DW project intakes, discharge pumps, and boat docks. Sites for the facilities would be relatively steep, riprapped levee slopes. The facilities are unlikely to be located in preferred spawning or rearing habitat of Sacramento splittail.

Loss of habitat would have significant adverse effects on localized splittail reproduction. If intake siphons, discharge pumps, or boat docks were located in or near shallow vegetated habitat, splittail spawning and rearing habitat could be lost or altered. The area of lost habitat would be small relative to the area of similar habitat available in the Delta, and such loss would have minimal effects on splittail populations.

Splittail spawn over flooded vegetation. Most of the seasonally flooded spawning habitat, representing most of the available spawning habitat, is upstream of the Delta. Spawning area increases as high flows inundate seasonally available habitats. Splittail abundance, although correlated with Delta outflow, is likely not directly dependent on outflow but rather on flooding of habitats upstream of the Delta. DW project operations would not affect splittail spawning habitat upstream of the Delta.

Direct Entrainment. Splittail larvae and early juveniles could be entrained in DW diversions if the DW intakes are located in areas that support spawning and rearing, but entrainment would affect only local populations. The presence of adult and juvenile splittail near DW project diversions (Figure 3F-3) may coincide with the timing of diversions (Table 3A-7 in Chapter 3A). Adult and juvenile splittail would be efficiently screened from DW project diversions. Also, unscreened agricultural diversions would be eliminated from the DW project islands and direct entrainment (and impingement) could be reduced. Operations of Alternative 1 would have less-than-significant adverse entrainment effects on adult and older juvenile Sacramento splittail.

Longfin Smelt

DW project effects on longfin smelt were evaluated for transport of larvae and juveniles during January-April; habitat availability for larvae and early juveniles during January-May; and entrainment of larvae, juveniles, and adults throughout the year.

Transport. Operations under Alternative 1 would have adverse effects on longfin smelt transport and entrainment loss. However, spawning location is outside the primary influence of central and south Delta diversions, and transport effects of total Delta diversions would be substantially less for longfin smelt than the effects described for delta smelt (Figure 3F-10). Longfin smelt spawn primarily in the Sacramento River; in the confluence area; and, when salinity conditions are adequate, in Suisun Bay.

The entrainment indices for longfin smelt range from 0.0% to 21% (Figure 3F-10). The change in the entrainment indices for longfin smelt under operations of Alternative 1 ranges from 0% to 5.6% and the average index for the 70-year simulation is 0.8% (Table 3F-5).

Simulated diversions onto the DW project islands were greater for periods when longfin smelt would be present (Table 3A-7 in Chapter 3A) than when delta smelt are present; therefore, DW diversions are more likely to affect longfin smelt. Peak occurrence of longfin smelt larvae is during February and March (see "Affected Environment"). Discharges for export, however, were simulated to occur after the abundance of longfin smelt in the Delta would have declined. Therefore, DW discharge for export would have minimal effects on the entrainment index for longfin smelt.

As with delta smelt, the assumed spawning distribution can have a substantial effect on the simulated entrainment index for Delta diversions (Appendix F2). For the impact assessment, all longfin smelt were assumed to spawn on the Sacramento River side of the Delta. In wetter periods (i.e., when water is available for DW diversions), spawning may be distributed from Rio Vista downstream to Suisun Bay. DW diversion effects on transport conditions in the confluence and Suisun Bay would be less than the effects shown in Figure 3F-10.

Optimal Salinity Habitat. Longfin smelt year-class survival may be related to optimal salinity habitat area.

DW project diversions would have less-than-significant adverse effects on longfin smelt habitat area. Under simulated operations of the No-Project Alternative and Alternative 1 for 1922-1991, the annual weighted habitat area available for longfin smelt ranged from 122 km^2 to 248 km^2 (Figure 3F-11). Change in habitat area under DW project operations relative to the No-Project Alternative conditions ranged from -7.29 km^2 to 3.04 km^2 and averaged -0.87 km^2 for the 70-year simulation (Table 3F-6). The greater estimated percent change in habitat area for longfin smelt compared with that for delta smelt results from the coincidence of larval longfin smelt presence and simulated DW project diversions to fill the reservoir islands (Table 3A-7 in Chapter 3A). Reductions in habitat area would be infrequent and substantial habitat area (i.e., greater than 122 km^2) would remain (Figure 3F-11).

Direct Entrainment. Potential entrainment of larvae is described above under "Transport". Alternative 1 would likely have minimal and less-than-significant adverse effects on direct entrainment of adult and older juvenile longfin smelt. Although the presence of adult and juvenile longfin smelt near DW project intake siphons (Figure 3F-3) may coincide with the timing of diversions (Table 3A-7 in Chapter 3A), older juvenile and adult longfin smelt would generally be found downstream of the central Delta. Use of fish screens would reduce adverse effects of diversions on adults and larger juveniles.

Summary of Project Impacts and Recommended Mitigation Measures

Impact F-4: Potential Increase in the Mortality of Chinook Salmon Resulting from the Indirect Effects of DW Project Diversions and Discharges on Flows. Simulations of DW project operations show that DW project diversions and discharges for export could increase the mortality of juvenile chinook salmon out-migrating through the Delta. Increased mortality would result primarily from indirect effects of the project on central Delta flow conditions; changes in flows may affect successful migration of chinook salmon to the Bay.

Effects would be less than significant for out-migrant chinook salmon originating in the Sacramento River (including the fall, late fall, winter, and spring runs), but could be significant for juveniles originating in the Mokelumne and San Joaquin Rivers. If DW diversions to fill the reservoir islands were made during major out-migration periods of Mokelumne and San Joaquin River chinook salmon, the impacts on the out-migrants would be significant. The impact is considered significant because nearly all the annual production of Mokelumne and San Joaquin River chinook salmon could be affected and DW diversions could substantially change cross-Delta flow. DW discharge to export would have a relatively small effect on cross-Delta flow and therefore would have less impacts on Mokelumne and San Joaquin River out-migrants.

Daily DW project effects could be greater or less than the effects described for monthly conditions in this assessment. Implementing Mitigation Measure F-3 would reduce Impact F-4 (daily and monthly) to a less-than-significant level.

Mitigation Measure F-3: Operate the DW Project under Operations Objectives That Would Minimize Changes in Cross-Delta Flow Conditions during Peak Out-Migration of Mokelumne and San Joaquin River Chinook Salmon. DW shall implement fixed and adaptive management measures that would minimize indirect entrainment losses of juvenile chinook salmon originating in the Mokelumne and San Joaquin Rivers.

- **Fixed Measures.** DW would not divert water to fill the reservoir islands during April-June. DW project discharge to export would not be allowed to increase daily cross-Delta flow conditions (i.e., CDFP or other appropriate parameter) by more than 10% during April, May, and June. Cross-Delta flow conditions would be calculated using the fish transport model DeltaMOVE or another suitable model of transport conditions. Fixed measures would be implemented until the adaptive management plan is implemented and the effectiveness of adaptive measures has been demonstrated.

- **Adaptive Measures.** DW, in cooperation with SWRCB and in consultation with USFWS, NMFS, and DFG, would develop an adaptive management plan that may include the following:

  - **Methods to estimate the anticipated effects of DW diversions on migration of juvenile chinook salmon originating in the Mokelumne and San Joaquin Rivers.** A methodology would be developed that would provide estimates of actual or anticipated occurrence or movement of juvenile chinook salmon. The estimates may include real-time salvage of juvenile salmon at the CVP and SWP fish protection facilities or simulation of transport conditions and subsequent movement of juvenile salmon. Transport conditions (e.g., CDFP) may be simulated with the fish transport model used in this assessment (DeltaMOVE) or another suitable model of transport conditions. Estimates of transport conditions with and without DW diversions would be based on anticipated Delta diversion levels, inflows, channel flows, tidal flows, and facility operations; other chemical and physical conditions (e.g., temperature and salinity); and measured population distribution of juvenile chinook salmon. Existing or new sampling programs would be identified that provide information on the distribution of juvenile salmon out-migrants in the Delta during April and May.

  - **Target migration criteria.** Target migration movement criteria may include Delta transport conditions or the proportion of the population entrained at the SWP and CVP fish protection facilities. The target values would be based on the distribution and abundance of juvenile salmon originating in the Mokelumne and San Joaquin Rivers.

  - **DW operations objectives.** Specific operations objectives for DW diversions would be developed based on the relationship between anticipated DW-affected and target migration criteria.

  - **Analysis of effectiveness.** A methodology would be included that allows assessment of effectiveness of the real-time adaptive operations management plan. The methodology may consist of analysis of available data and monitoring requirements for collection of information specific to DW project operations.

  - **Alternative actions.** Actions to mitigate unavoidable DW project impacts would be identified and could include adjustments to future DW diversions and non-operations actions (e.g., habitat restoration).

Impact F-5: Reduction in Downstream Transport and Increase in Entrainment Loss of Striped Bass Eggs and Larvae, Delta Smelt Larvae, and Longfin Smelt Larvae. When the presence of planktonic fish eggs and larvae coincides with DW diversion and discharge to export, increased net flow to the central and south Delta could increase entrainment losses. Reduced net flow to the lower San Joaquin River and to Suisun Bay resulting from DW project diversions could, depending on distribution of fish eggs and larvae, increase vulnerability to transport toward the central and south Delta. Increased entrainment loss of eggs and larvae would be small (i.e., generally less than 1%) relative to existing losses. The impact, however, is considered significant because existing losses to other diversions potentially reduce population abundance and contribute to recent downward trends in the population abundance of striped bass, delta smelt, and longfin smelt.

Daily DW project effects could be greater or less than the effects described for monthly conditions in this assessment. Implementing Mitigation Measure F-4 would reduce Impact F-5 to a less-than-significant level.

Mitigation Measure F-4: Operate the DW Project under Operations Objectives That Would Minimize Adverse Transport Effects on Striped Bass, Delta Smelt, and Longfin Smelt. DW shall implement fixed and adaptive management measures that would minimize entrainment loss and adverse effects on transport (toward Suisun Bay) of planktonic eggs and larvae.

- **Fixed Measures.** Fixed measures would be the same as described in Mitigation Measure F-3.

- **Adaptive Measures**. DW, in cooperation with SWRCB and the Corps and in consultation with USFWS and DFG, would develop an adaptive management plan that may include the following:

  - **Methods to estimate existing and DW-affected transport indices.** The fish transport model used in this assessment (DeltaMOVE) or another suitable model of transport conditions would be used to estimate transport indices with and without DW operations based on anticipated Delta diversion levels, inflows, channel flows, tidal flows, and facility operations (e.g., DCC gates and Old River barrier); other chemical and physical conditions (e.g., temperature and salinity); and measured distribution and abundance of striped bass eggs and larvae, delta smelt larvae, and longfin smelt larvae. The daily estimation period for the indices will be appropriate to enable DW to change project operations to minimize impacts.

  - **Target transport and entrainment loss index values**. Target transport and entrainment loss index values would be identified and justified for striped bass, delta smelt, and longfin smelt. Target transport index values may be developed through the ongoing California and federal Endangered Species Act consultation with USFWS and DFG or through other appropriate means.

  - **DW operations objectives**. Specific operations objectives for DW diversions and discharges for export would be developed based on the relationship between anticipated, DW-affected, and target transport and entrainment loss indices. The objectives would include flexibility to allow integration of DW project operations into the California Water Policy Council and Federal Ecosystem Directorate (CALFED) operations coordination group process.

  - **Analysis of effectiveness**. A methodology would be included that allows assessment of the effectiveness of the real-time adaptive operations management plan. The methodology may consist of analysis of available data and monitoring requirements for collection of information specific to DW project operations.

  - **Alternative actions**. Actions to mitigate unavoidable DW project impacts would be identified and could include adjustments to future DW operations and non-operations actions (e.g., habitat restoration).

Impact F-6: Change in Area of Optimal Salinity Habitat. DW project diversions could reduce Delta outflow by as much as 9,000 cfs during initial days of filling and could cause X2 to shift upstream. The upstream shift in X2 could reduce the area of optimal salinity habitat available to striped bass, delta smelt, and longfin smelt. The effect on habitat area, however, depends on the duration of the upstream shift in X2 (i.e., diversion) and the coincidence of habitat needs with operations that may affect area. The analysis of habitat area showed that DW project operations could increase habitat area during some years and reduce habitat area during others. The impact is considered less than significant because:

- the change in habitat area would be small relative to the total availability of habitat;
- DW diversions would be infrequent during April through August when optimal salinity habitat needs are important for production of striped bass, delta smelt, and longfin smelt (San Francisco Estuary Project 1993);
- the direct effects of DW diversion on optimal salinity habitat area would be of short duration (about one month) relative to the period of estuarine habitat needs; and
- forgone DW agricultural diversions during April through August could slightly increase optimal salinity habitat area.

Mitigation. No mitigation is required.

Impact F-7: Increase in Entrainment Loss of Juvenile Striped Bass and Delta Smelt. When juvenile striped bass and delta smelt are distributed primarily in the Delta, export of the first uncontrolled flow to occur during a water year (i.e., uncontrolled flow during November-January) results in high entrainment at the SWP and CVP Delta export pumps. DW project diversions could alter Delta flow patterns; affect environmental cues that determine successful migration to the Bay; and, subsequently, increase entrainment losses of striped bass and delta smelt at the SWP and CVP Delta pumps. This impact is considered significant because losses of juveniles would potentially reduce population abundance and may contribute to recent downward trends in the population abundance of striped bass and delta smelt.

Daily DW project effects could be greater or less than the effects described for monthly conditions in this assessment. Implementing Mitigation Measure F-5 would reduce Impact F-7 to a less-than-significant level.

Mitigation Measure F-5: Operate the DW Project under Operations Objectives That Would Minimize Entrainment of Juvenile Striped Bass and Delta Smelt. DW shall implement fixed and adaptive management measures that would minimize entrainment loss of juvenile striped bass and delta smelt during November-January diversions by DW.

- **Fixed Measures.** During November-January, DW would not divert to fill the reservoir islands until after X2 is at or downstream of Chipps Island for any 5 consecutive days. After the Chipps Island criterion is met, DW would divert to fill the reservoir islands only when X2 is at or downstream of Collinsville.

- **Adaptive Measures.** DW, in cooperation with SWRCB and the Corps and in consultation with USFWS and DFG, would develop an adaptive management plan that may include the following:

  - **Methods to estimate the anticipated effects of DW diversions on entrainment of juvenile striped bass and delta smelt.** A methodology would be developed that would provide estimates of actual or anticipated entrainment of juvenile striped bass and delta smelt. The estimates may include real-time salvage of striped bass and delta smelt at the CVP and SWP fish protection facilities or simulation of transport conditions and subsequent entrainment of bass and smelt. Transport conditions (e.g., CDFP) may be simulated with the fish transport model used in this assessment (DeltaMOVE) or another suitable model of transport conditions. Estimates of transport conditions with and without DW diversions would be based on anticipated Delta diversion levels, inflows, channel flows, tidal flows, and facility operations; other chemical and physical conditions (e.g., temperature and salinity); and measured population distribution of juvenile striped bass and delta smelt. Existing or new sampling programs would be identified that provide information on the distribution in the Delta and Suisun Bay during November-January.

  - **Target entrainment values.** DW intakes will include effective fish screens and DW diversions would not directly entrain juvenile striped bass and delta smelt. Target entrainment values may be established for DW project operations based on entrainment at the SWP and CVP fish protection facilities. The target values would be based on the distribution and abundance of juvenile striped bass and delta smelt.

  - **DW operations objectives.** Specific operations objectives for DW diversions would be developed based on the relationship between anticipated DW-affected and target entrainment criteria.

  - **Analysis of effectiveness.** A methodology would be included that allows assessment of effectiveness of the real-time adaptive operations management plan. The methodology may consist of analysis of available data and monitoring requirements for collection of information specific to DW project operations.

  - **Alternative actions.** Actions to mitigate unavoidable DW project impacts would be identified and could include adjustments to future DW diversions and non-operations actions (e.g., habitat restoration).

Impact F-8: Increase in Entrainment Loss of Juvenile American Shad and Other Species. DW diversions could increase entrainment loss of juvenile American shad and other species. The impact is considered less than significant because DW reservoir island diversions would operate with effective fish screens that minimize direct entrainment loss. On the habitat islands, existing unscreened agricultural diversions would be screened.

Mitigation. No mitigation is required.

IMPACTS AND MITIGATION MEASURES OF ALTERNATIVE 2

Alternative 2 is similar to Alternative 1 and involves storage of water on Bacon Island and Webb Tract (reservoir islands) and management of Bouldin Island and Holland Tract as habitat islands. In DeltaSOS simulations of operations of Alternative 2, it is assumed that diversions onto the reservoir islands could occur any time when surplus flows are available in the Delta (i.e., when 1995 WQCP criteria are met). Water discharged from the reservoir islands is assumed to be Delta inflow. Export of DW discharges under Alternative 2 by the CVP and SWP Delta pumping facilities is not subject to the 1995 WQCP criteria for percentage of Delta inflow diverted (see Chapter 3A, "Water Supply and Water Project Operations").

Effects of operations under Alternative 2 were determined through comparison of flow and habitat conditions for operations and facilities simulated by DeltaSOS with and without the DW project (i.e., under Alternative 2 and under the No-Project Alternative). Table 3A-9 in Chapter 3A, "Water Supply and Water Project Operations", and Tables A3-10a and A3-10b in Appendix A3, "DeltaSOS Simulations of the Delta Wetlands Project Alternatives", show the results of DeltaSOS simulations of reservoir island diversions and discharges under Alternative 2 based on hydrologic conditions for 1922-1991. Habitat island diversions under the DW project are the same as for Alternative 1 (Table 3A-2 in Chapter 3A and Table A1-7 in Appendix A1, "Delta Monthly Water Budgets for Operations Modeling of the Delta Wetlands Project").

Effects of Construction Activities

Effects of construction activities under Alternative 2 would be the same as described for Alternative 1.

Effects on Water Quality

Under Alternative 2, effects of DW project operations on water quality would be the same as described for Alternative 1.

Potential Flow and General Habitat Effects

This section discusses potential general effects on fish habitat, transport, and entrainment that could result from implementing Alternative 2.

Effects on Delta Outflow

The maximum assumed DW diversion rate is the same for Alternatives 1 and 2, (maximum average monthly diversion rate of 4,000 cfs). DW project diversions under Alternative 2 would be similar to diversions under Alternative 1. The effects on outflow also would be similar (Table 3F-1).

Effects on Salinity

Upstream shift in X2 could occur slightly more often under Alternative 2 (Table 3F-2). The impacts of upstream shift in X2 on fish habitat conditions under Alternative 2 would be similar to the impacts described for Alternative 1.

Effects on Delta Flow Patterns

The effects of DW operations under Alternative 2 on Delta flow patterns would be the same as those under Alternative 1. DCC and Georgiana Slough flows and San Joaquin River flows at Stockton would not be affected by DW operations (Appendix A3, Tables A3-5 and A3-10). The effects on QWEST volume would be similar to effects described for Alternative 1. Simulated DW operations under Alternative 2 resulted in 14 reversals of positive QWEST for the 70-year monthly simulation, the same as under Alternative 1.

DW diversion effects on Old and Middle River flow under Alternative 2 would be similar to those described for Alternative 1 (Table 3F-3). Simulated discharge for export, however, more frequently resulted in increased Old and Middle River flow to the south during February, March, May, and June. Compared with flow under Alternative 1, Old and Middle River flow under Alternative 2 increased less frequently during April, July, August, and September (Appendix A3, Tables A3-7b and A3-10b).

The less frequent increases in southerly flow simulated for Old and Middle Rivers during April, July, August, and September resulted from earlier discharge to export (i.e., during February and March), which would be allowed when CVP and SWP export of DW discharge is not subject to strict interpretation of the 1995 WQCP criteria for percentage of inflow diverted.

Potential Species-Specific Effects

Species abundance indices and habitat conditions were compared for operations under the No-Project Alternative and Alternative 2. Results of the assessment of effects are described below for each of the six target species of this assessment.

Chinook Salmon

The following discussions describe changes in the mortality index of juvenile chinook salmon that were estimated to result from simulated DW project operations under Alternative 2 relative to operations of the No-Project Alternative. It is assumed that DW project operations would not affect upstream operations; therefore, migration timing under Alternative 2 is identical to migration timing under Alternative 1.

Figure 3F-4 shows the Delta migration mortality for fall-run chinook salmon originating in the Sacramento River. The total Delta mortality index simulated for the 1922-1991 period under Alternative 2 ranges from about 14% to 75% of the annual production of fall-run juveniles entering the Delta (Table 3F-4). The change in the mortality index attributable to DW project operations simulated for Alternative 2 cannot be discerned in Figure 3F-4. The increase averages about 0.04% and ranges from -0.02% to 0.32%. Reduced mortality is the result of agricultural diversions being forgone during years when the reservoir islands would not fill or discharge.

The relatively small effect of DW operations on juvenile fall-run chinook salmon originating in the Sacramento River is attributable to the timing of fall-run migration relative to timing of DW operations and is similar to effects described for Alternative 1.

Effects of DW project operations under Alternative 2 on fall-run juveniles originating in the Mokelumne and San Joaquin Rivers would also be similar to effects described for Alternative 1.

Figure 3F-5 shows the winter-run chinook salmon migration mortality index attributable to all Delta diversions for the 70-year simulation. The total Delta mortality index simulated for the 1922-1991 period ranges from 6% to 17% of the annual production of winter-run chinook salmon juveniles (Table 3F-4). Simulated DW project operations under Alternative 2 changed mortality relative to mortality under the No-Project Alternative by -0.02% to 0.46% (an average of 0.12%).

The increased mortality under Alternative 2 would have a small, but significant, indirect adverse impact on juvenile chinook salmon, similar to the effect described for Alternative 1.

Striped Bass

Transport. DW operations under Alternative 2 could have significant adverse impacts on transport of striped bass eggs and larvae, but the effects would be slightly less than those described for Alternative 1.

Figure 3F-6 shows the total annual entrainment loss of striped bass attributable to all Delta diversions for the 70-year simulation. Total Delta entrainment loss simulated for 1922-1991 ranges from about 1% to 31% of the annual production of striped bass larvae (Table 3F-5). The simulations indicated that DW project operations under Alternative 2 could change the annual entrainment loss relative to loss under the No-Project Alternative by -0.23% to 1.6%. Reduced entrainment is the result of agricultural diversions being forgone during years when the reservoir islands would not fill or discharge.

Optimal Salinity Habitat. Change in habitat area under Alternative 2 relative to area under the No-Project Alternative was the same as described for Alternative 1 (Figure 3F-7 and Table 3F-6).

Direct Entrainment. As under Alternative 1, DW project diversions under Alternative 2 would result in a significant indirect entrainment impact on juvenile striped bass. Juvenile striped bass would be screened from DW reservoir and habitat island diversions under Alternative 2 and direct entrainment would be minimized.

American Shad

As under Alternative 1, DW project operations under Alternative 2 would likely have less-than-significant impacts on survival of American shad. Juvenile shad would be screened from DW reservoir and habitat island diversions and the project would likely cause minimal direct entrainment. As with striped bass, indirect effects of DW project diversions could increase juvenile entrainment at the SWP and CVP Delta pumps.

Delta Smelt

Transport. DW project operations under Alternative 2 would have a significant adverse impact on delta smelt survival through effects on transport flow.

Figure 3F-8 shows the total annual entrainment loss of delta smelt attributable to all Delta diversions for the 70-year simulation. Total Delta entrainment loss simulated for 1922-1991 ranges from about 1% to 36% of the annual production of delta smelt larvae (Table 3F-5). The simulations indicated that DW project operations under Alternative 2 could change the annual entrainment loss relative to loss under the No-Project Alternative by 0 to 3.4%. DW operations under Alternative 2 could have adverse effects on transport of delta smelt larvae and the effects would be slightly greater than those described for Alternative 1.

Optimal Salinity Habitat. DW diversions would have less-than-significant effects on delta smelt habitat area. Change between habitat area simulated for the same year for Alternative 2 and for the No-Project Alternative ranged from -1.11 km^2 to 1.05 km^2 (average increase in area for the 70-year simulation of 0.05 km^2) (Figure 3F-9 and Table 3F-6). Increased area would result from DW agricultural diversions being forgone during May-July.

Direct Entrainment. As described for Alternative 1, juvenile and adult delta smelt would be screened from DW reservoir and habitat island diversions under Alternative 2. The DW project would likely cause minimal direct entrainment of juvenile and adult delta smelt. Indirect effects of DW project operations (i.e., effects on environmental cues that determine successful migration to the Bay), however, could increase juvenile entrainment at the SWP and CVP Delta pumps and contribute to a significant adverse impact.

Sacramento Splittail

The effects of DW operations and facilities under Alternative 2 on overall population abundance would be the same as those desribed for Alternative 1.

Longfin Smelt

Transport. DW operations under Alternative 2 would have less-than-significant adverse impacts on transport of longfin smelt larvae, and the effects would be slightly greater than those described for Alternative 1.

Figure 3F-10 shows the total annual entrainment loss of longfin smelt attributable to all Delta diversions for the 70-year simulation. Total Delta entrainment loss simulated for 1922-1991 ranged from about 0 to 22% of the annual production of longfin smelt larvae (Table 3F-5). The simulations indicated that DW project operations under Alternative 2 could change the annual entrainment loss relative to loss under the No-Project Alternative by 0 to 6.4%.

Optimal Salinity Habitat. Similar to Alternative 1, DW diversions under Alternative 2 would have less-than-significant adverse impacts on longfin smelt habitat area. Change in habitat area under Alternative 2 relative to area under the No-Project Alternative ranged from -7.29 km^2 to 1.99 km^2 (average decrease in area for the 70-year simulation of -0.93 km^2) (Figure 3F-11 and Table 3F-6). The average reduction in habitat area under Alternative 2 would be slightly larger than that described for Alternative 1.

Direct Entrainment. As described for Alternative 1, juvenile and adult longfin smelt would be screened from DW reservoir and habitat island diversions under Alternative 2. The DW project would likely cause minimal and less-than-significant impacts on direct and indirect entrainment of juvenile and adult longfin smelt.

Summary of Project Impacts and Recommended Mitigation Measures

The impacts of Alternative 2 are similar to the impacts described for Alternative 1. The same mitigation measures would apply to impacts of Alternative 2.

IMPACTS AND MITIGATION MEASURES OF ALTERNATIVE 3

Alternative 3 involves storage of water on all four DW project islands, with secondary uses for wildlife habitat and recreation; the portion of Bouldin Island north of SR 12 would provide limited habitat. Existing agricultural diversions would cease under Alternative 3. Simulation of DW project operations under Alternative 3 is based on the assumption that diversions onto the reservoir islands could occur any time of the year when surplus flows are available in the Delta (i.e., 1995 WQCP criteria are met). Water discharged from the reservoir islands is assumed to be Delta inflow; it is assumed that DW discharges exported by the CVP and SWP Delta pumping facilities would not be subject to the 1995

WQCP percent inflow criteria (See Chapter 3A, "Water Supply and Water Project Operations").

Effects of DW project operations under Alternative 3 were determined though comparison of flow and habitat conditions for operations and facilities simulated by DeltaSOS with and without the DW project (i.e., under Alternative 3 and under the No-Project Alternative). Table 3A-11 in Chapter 3A, "Water Supply and Water Project Operations", and Tables A3-13a and A3-13b in Appendix A3, "DeltaSOS Simulations of the Delta Wetlands Project Alternatives", show the results of DeltaSOS simulations of DW reservoir island diversions and discharges based on hydrologic conditions for 1922-1991.

Effects of Construction Activities

Effects of construction activities under Alternative 3 would be similar to those described for Alternative 1. Additional intake facilities, fish screens, and discharge facilities would be constructed on Bouldin Island, Holland Tract, and Webb Tract under Alternative 3 compared with facilities and fish screens under Alternatives 1 and 2.

Summary of Project Impacts and Recommended Mitigation Measures

Impact F-9: Alteration of Habitat. Construction of intake facilities and fish screens, discharge facilities, and boat docks could have significant adverse impacts on spawning and rearing habitat used by Delta fish species. Additional intake structures, fish screens, and discharge structures would be constructed on Bouldin Island, Holland Tract, and Webb Tract relative to construction under Alternatives 1 and 2. The loss of habitat area, however, would still be small relative to the total area of similar habitat in the Delta, and such habitat loss would have minimal effects on fish populations. The impact, however, is considered significant because historical and ongoing activities (e.g., dredging, placement of riprap, and levee construction) have destroyed substantial areas of spawning and rearing habitat in the Delta, and recent downward trends in the population abundance of delta smelt and Sacramento splittail may indicate the need to preserve the remaining habitat.

Implementing Mitigation Measure F-1 would reduce Impact F-9 to a less-than-significant level.

Mitigation Measure F-1: Implement Fish Habitat Management Actions. This mitigation measure is described above under "Impacts and Mitigation Measures of Alternative 1".

Effects on Water Quality

Under Alternative 3, effects of DW project operations on water quality would be similar to those described for Alternative 1. Additional discharge would occur from the two additional reservoir islands and Webb Tract.

Summary of Project Impacts and Recommended Mitigation Measures

Impact F-10: Increase in Temperature-Related Mortality of Juvenile Chinook Salmon. This impact is described above under Impact F-2. This impact is considered significant. Implementing Mitigation Measure F-2 would reduce Impact F-10 to a less-than-significant level.

Mitigation Measure F-2: Monitor the Water Temperature of DW Discharges and Reduce DW Discharges to Avoid Producing Any Increase in Channel Water Temperature Greater Than 1°F. This mitigation measure is described above under "Impacts and Mitigation Measures of Alternative 1".

Impact F-11: Potential Increase in Accidental Spills of Fuel and Other Materials. This impact is described above under Impact F-3. The impact is considered less than significant.

Mitigation. No mitigation is required.

Potential Flow and General Habitat Effects

This section discusses potential general effects on fish habitat, transport, and entrainment that could result from implementing Alternative 3.

Effects on Delta Outflow

The average monthly diversion rate under Alternative 3 would be 6,000 cfs. The maximum average daily diversion rate would be 9,000 cfs, the same as under Alternatives 1 and 2. The seasonal timing of DW project diversions under Alternative 3 would be similar to the seasonal timing of diversions under Alternative 1 (Tables 3A-7 and 3A-11 in Chapter 3A), although the magnitude of diversions would increase. The effects on outflow would also be similar to the those described for Alternative 1 (Table 3F-1), although outflow would be reduced more often and to a greater extent.

Effects on Salinity

Effects on X2 would be greater than those described for Alternative 1 (Table 3F-2). X2 would shift upstream more often under Alternative 3. The impacts of reduced outflow and upstream shift in X2 on fish habitat conditions under Alternative 3 would be similar to, but greater than, the impacts described for Alternative 1.

Effects on Delta Flow Patterns

The effects of DW operations under Alternative 3 on Delta flow patterns would be similar to effects described for Alternative 1. DCC and Georgiana Slough flows and San Joaquin River flows at Stockton would not be affected by DW operations (Appendix A3, Tables A3-5 and A3-14). The effects on QWEST volume would be greater than effects described for Alternative 1. Simulated DW operations under Alternative 3 resulted in 19 reversals of positive QWEST for the 70-year monthly simulation, five more than under Alternative 1.

The increased magnitude and frequency of diversion under Alternative 3 would increase the rate of Old and Middle River flows to the south (Table 3F-3). Compared with Alternative 1, discharge for export under Alternative 3 would result in more frequent increased Old and Middle River flow to the south during February, March, May, and June and less frequent increased flow to the south during April, July, August, and September (Appendix A3, Tables A3-7b and A3-13b).

The less frequent increases in southerly flow simulated for Old and Middle Rivers during April, July, August, and September resulted from earlier discharge to export (i.e., during February and March), which would be allowed when CVP and SWP export of discharge is not subject to strict interpretation of the 1995 WQCP criteria for percentage of inflow diverted.

The simulated pattern of discharge for export for Alternative 3 is similar to the pattern simulated for Alternative 2 (Appendix A3, Table A3-10b).

Potential Species-Specific Effects

Species abundance indices and habitat conditions were compared for operations under the No-Project Alternative and Alternative 3. Results of the assessment of effects are described below for each of the six target species of this assessment.

Chinook Salmon

The following discussions describe changes in the mortality index of juvenile chinook salmon that were estimated to result from simulated DW project operations under Alternative 3 relative to operations of the No-Project Alternative. It is assumed that DW project operations would not affect upstream operations; therefore, migration timing under Alternative 3 would be identical to migration timing under Alternative 1.

The relatively small effect of DW operations on juvenile fall-run chinook salmon originating in the Sacramento River is attributable to the timing of fall-run migration relative to timing of DW operations and is similar to the efffects described for Alternative 1. Figure 3F-4 shows the Delta migration mortality for fall-run chinook salmon originating in the Sacramento River. The total Delta mortality index simulated for the 1922-1991 period under Alternative 3 ranges from about 14% to 75% of the annual production of fall-run juveniles entering the Delta (Table 3F-4). The change in the mortality index attributable to DW project operations simulated for Alternative 3 cannot be discerned in Figure 3F-4. The increase averages about 0.05% and ranges from -0.04% to 0.33%. Reduced mortality is the result of agricultural diversions being forgone during years when the reservoir islands would not fill or discharge.

Effects of DW project operations under Alternative 3 on fall-run juveniles originating in the Mokelumne and San Joaquin Rivers would be similar to, but greater than, effects described for Alternative 1.

Figure 3F-5 shows the winter-run migration mortality index attributable to all Delta diversions for the 70-year simulation. The total Delta mortality index simulated for the 1922-1991 period ranges from 6% to 17% of the annual production of winter-run chinook salmon juveniles (Table 3F-4). Simulated DW project operations under Alternative 3 changed mortality relative to mortality under the No-Project Alternative by -0.01% to 0.74% (an average of 0.18%).

The increased mortality under Alternative 3 would have a small but significant indirect adverse impact on juvenile chinook salmon greater than the effects described for Alternative 1.

Striped Bass

Transport. DW operations under Alternative 3 would have significant adverse impacts on transport of striped bass eggs and larvae, and the effects would be slightly greater than those described for Alternative 1.

Figure 3F-6 shows the total annual entrainment loss of striped bass attributable to all Delta diversions for the 70-year simulation. Total Delta entrainment loss simulated for 1922-1991 ranges from about 1% to 31% of the annual production of striped bass larvae (Table 3F-5). The simulations indicated that DW project operations under Alternative 3 could change the annual entrainment loss relative to loss under the No-Project Alternative by -0.02% to 1.7%. Reduced entrainment is the result of agricultural diversions being forgone during years when the reservoir islands would not fill or discharge.

Optimal Salinity Habitat. Change in habitat area under Alternative 3 relative to area under the No-Project Alternative ranged from -1.82 km^2 to 2.86 km^2 (average increase in area for the 70-year simulation of 0.23 km^2) (Figure 3F-7 and Table 3F-6). Increased area would result from DW agricultural diversions being forgone during May-July (the average increase in habitat area estimated for Alternative 3 is slightly greater than that estimated for Alternatives 1 and 2 because habitat island diversions are absent under Alternative 3).

Direct Entrainment. As described for Alternative 1, DW project diversions under Alternative 3 would cause a significant indirect entrainment impact on juvenile striped bass. Juvenile striped bass would be screened from DW reservoir and habitat island diversions under Alternative 3 and direct entrainment would be minimized.

American Shad

As under Alternative 1, DW project operations under Alternative 3 would likely have less-than-significant impacts on survival of American shad. Juvenile shad would be screened from DW reservoir island diversions and the project would likely cause minimal direct entrainment. As with striped bass, indirect effects of DW project diversions could increase juvenile entrainment at the SWP and CVP Delta pumps.

Delta Smelt

Transport. DW operations under Alternative 3 would have significant adverse impacts on transport of delta smelt larvae. The effects would be slightly greater than those described for Alternative 1.

Figure 3F-8 shows the total annual entrainment loss of delta smelt attributable to all Delta diversions for the 70-year simulation. Total Delta entrainment loss simulated for 1922-1991 ranges from about 1% to 36% of the annual production of delta smelt larvae (Table 3F-5). The simulations indicated that DW project operations under Alternative 3 could change the annual entrainment loss relative to loss under the No-Project Alternative by 0 to 4.1%.

Optimal Salinity Habitat. DW diversions would have less-than-significant effects on habitat area for delta smelt. Change in habitat area under Alternative 3 relative to area under the No-Project Alternative ranged from -1.61 km^2 to 2.36 km^2 (average increase in area for the 70-year simulation of 0.04 km^2) (Figure 3F-9 and Table 3F-6). Increased area would result from DW agricultural diversions being forgone during May-July.

Direct Entrainment. As described for Alternative 1, juvenile and adult delta smelt would be screened from DW reservoir island diversions under Alternative 3. The DW project would likely cause minimal direct entrainment of juvenile and adult delta smelt. Indirect effects of DW project operations (i.e., effects on predation and on environmental cues that determine successful migration to the Bay), however, could increase juvenile entrainment at the SWP and CVP Delta pumps and contribute to a significant adverse impact.

Sacramento Splittail

The effects of DW operations and facilities under Alternative 3 on overall population abundance would be similar to or slightly greater than the effects described for Alternative 1.

Longfin Smelt

Transport. DW operations under Alternative 3 would have less-than-significant adverse effects on transport of longfin smelt larvae. The effects would be greater than those described for Alternative 1 (Table 3F-5).

Figure 3F-10 shows the total annual entrainment loss of longfin smelt attributable to all Delta diversions for the

70-year simulation. Total Delta entrainment loss simulated for 1922-1991 ranged from about 0 to 22% of the annual production of longfin smelt larvae (Table 3F-5). The simulations indicated that DW project operations under Alternative 3 could change the annual entrainment loss relative to loss under the No-Project Alternative by 0 to 9.3%.

Optimal Salinity Habitat. Similar to Alternative 1, DW diversions under Alternative 3 would have less-than-significant adverse impacts on habitat area for longfin smelt. Change in habitat area under Alternative 3 relative to area under the No-Project Alternative ranged from -12.55 km^2 to 2.54 km^2 (average decrease in area for the 70-year simulation of 0.90 km^2) (Figure 3F-11 and Table 3F-6). The average reduction in habitat area under Alternative 3 would be slightly larger than that described for Alternative 1.

Direct Entrainment. As described for Alternative 1, juvenile and adult longfin smelt would be screened from DW reservoir diversions under Alternative 3. The DW project would likely cause less-than-significant impacts on direct and indirect entrainment of juvenile and adult longfin smelt.

Summary of Project Impacts and Recommended Mitigation Measures

Impact F-12: Potential Increase in the Mortality of Chinook Salmon Resulting from the Indirect Effects of DW Project Diversions and Discharges on Flows. This impact is described above under Impact F-4. The impact is considered significant. Implementing Mitigation Measure F-3 would reduce this impact to a less-than-significant level.

Mitigation Measure F-3: Operate the DW Project under Operations Objectives That Would Minimize Changes in Cross-Delta Flow Conditions during Peak Out-Migration of Mokelumne and San Joaquin River Chinook Salmon. This mitigation measure is described above under "Impacts and Mitigation Measures of Alternative 1".

Impact F-13: Reduction in Downstream Transport and Increase in Entrainment Loss of Striped Bass Eggs and Larvae, Delta Smelt Larvae, and Longfin Smelt Larvae. The impact is described above under Impact F-5. This impact is considered significant. Implementing Mitigation Measure F-4 would reduce Impact F-13 to a less-than-significant level.

Mitigation Measure F-4: Operate the DW Project under Operations Objectives That Would Minimize Adverse Transport Effects on Striped Bass, Delta Smelt, and Longfin Smelt. This mitigation measure is described above under "Impacts and Mitigation Measures of Alternative 1".

Impact F-14: Change in Area of Optimal Salinity Habitat. This impact is described above under Impact F-6. The impact is considered less than significant.

Mitigation. No mitigation is required.

Impact F-15: Increase in Entrainment Loss of Juvenile Striped Bass and Delta Smelt. The impact is described above under Impact F-7. This impact is considered significant. Implementing Mitigation Measure F-5 would reduce Impact F-15 to a less-than-significant level.

Mitigation Measure F-5: Operate the DW Project under Operations Objectives That Would Minimize Entrainment of Juvenile Striped Bass and Delta Smelt. This mitigation measure is described above under "Impacts and Mitigation Measures of Alternative 1".

Impact F-16: Increase in Entrainment Loss of Juvenile American Shad and Other Species. The impact is described above under Impact F-8. The impact is considered less than significant.

Mitigation. No mitigation is required.

IMPACTS AND MITIGATION MEASURES OF THE NO-PROJECT ALTERNATIVE

The No-Project Alternative (intensified agricultural use of the four DW project islands) represents Delta water supply conditions under implementation of the 1995 WQCP. Consumptive use would not measurably increase above existing conditions (see Chapter 3A, "Water Supply and Water Project Operations"). Simulated DW operations, Delta channel flows, exports, and Delta outflow are shown for the No-Project Alternative in Tables 3A-4 and 3A-5 in Chapter 3A and Tables A3-5 and A3-6 in Appendix A3, "DeltaSOS Simulations of the Delta Wetlands Project Alternatives".

The "Affected Environment" section above and Appendix F1, "Supplemental Information on the Affected

Environment for Fisheries", discuss historical conditions and the existing condition prior to implementation of the 1995 WQCP. The analysis of implementation of the 1995 WQCP and comparison with conditions prior to implementation of the 1995 WQCP is presented in Appendix 1, "Environmental Report", of the 1995 WQCP (SWRCB 1995).

Under the No-Project Alternative, the adverse effects of levee maintenance, discharge of agricultural drainage water, and unscreened agricultural diversions on the four DW project islands would continue, as would ongoing adverse effects of water project operations and facilities. Under the No-Project Alternative, simulated mortality indices for juvenile chinook salmon ranged from about 14% to 75% for fall run and from about 6% to 17% for winter run (Table 3F-4, Figures 3F-4 and 3F-5). Entrainment indices for the 70-year simulation averaged 26% for striped bass, 27% for delta smelt, and 8% for longfin smelt (Table 3F-5, Figures 3F-6, 3F-8, and 3F-10). The simulated available optimal salinity habitat area averaged 76 km^2 for striped bass, 51 km^2 for delta smelt, and 174 km^2 for longfin smelt (Table 3F-6, Figures 3F-7, 3F-9, and 3F-11).

Ongoing actions under the California and federal Endangered Species Acts (for winter-run chinook salmon, delta smelt, and possibly other species) may address adverse effects under the No-Project Alternative. Implementation of fish protection recommendations by the CALFED operations coordination group may also avoid or minimize adverse effects of water project operations that may occur under the No-Project Alternative.

CUMULATIVE IMPACTS

Cumulative impacts are the result of the incremental impacts of the proposed action when added to other past, present, and reasonably foreseeable future actions. DW project effects on fishery resources are inextricably tied to past and present environmental conditions. The cumulative impacts of the DW project alternatives therefore were evaluated in conjunction with past and present actions in the previous sections. The focus of this section is on evaluation of the impacts of the DW project alternatives added to impacts of other future projects.

The following discussion considers only those project effects that may contribute cumulatively to impacts on fishery resources in the Sacramento-San Joaquin Delta estuary and in streams and rivers tributary to the Delta. This cumulative impact evaluation is based on the following scenario: increased upstream demands; increased demands south and west of the Delta; an increased permitted pumping rate at the Banks Pumping Plant (see Chapter 3A, "Water Supply and Water Project Operations"); implementation of the DWR South and North Delta Projects; and additional storage south of the Delta in the Kern Water Bank, Los Banos Grandes Reservoir, Metropolitan Water District's Domenigoni Reservoir and Arvin-Edison projects, and the CCWD Los Vaqueros Reservoir.

Cumulative Impacts, Including Impacts of Alternative 1

Effects of Construction Activities

Future construction activities in the Delta will include continued maintenance of existing channels (dredging) and levees (placement of riprap and other levee reinforcement measures). New facilities (e.g., marinas, channel barriers) may be constructed as well, and existing channels may be modified to allow passage of boats or for conveyance of flow (e.g., the DWR North and South Delta Projects). Spawning and rearing habitat of delta smelt, Sacramento splittail, and other Delta species would be lost or altered. Existing programs and regulations (Corps and DFG regulations) would minimize or mitigate impacts. Additionally, habitat availability may be increased with implementation of existing programs (e.g., actions implemented as part of Category III measures in the Principles of Agreement on Bay-Delta Standards, Anadromous Fish Restoration Program under the CVPIA, and the SB34 Program, Delta Levees Project Management).

Impact F-17: Alteration of Habitat under Cumulative Conditions. Under future conditions, DW and others (e.g., DWR and reclamation districts) would maintain levees, boat docks, and intake and discharge facilities. Maintenance activities would include dredging and replacement of riprap. Alteration of spawning and rearing habitat under future conditions would adversely affect localized reproduction of delta smelt, Sacramento splittail, and resident species. The amount of habitat affected by construction and maintenance activities under cumulative conditions would be small relative to the total amount of similar habitat in the Delta, and the effects would generally be temporary. Additionally, total Delta habitat would likely increase under existing and future Delta programs (e.g., actions implemented as part of Category III measures in the Principles of Agreement on Bay-Delta Standards, Anadromous Fish Restoration Program under the CVPIA, and the SB34 Program, Delta

Levees Project Management). Therefore, this impact would be less than significant.

Mitigation. No mitigation is required.

Effects on Water Quality

Future water quality conditions (i.e., water temperature and concentrations of organic materials, toxics, and DO) in the Delta would be similar to conditions described for DW project operations in the discussions above. The effects of minor fuel and lubricant spills from individual boat engines and other boat-related discharge could be concentrated at Delta boat dock locations and could affect local populations of fish. These effects would increase under future conditions (see Chapter 3J, "Recreation and Visual Resources") because of increased boat-related activities.

Impact F-18: Potential Increase in Accidental Spills of Fuel and Other Materials under Cumulative Conditions. This impact is described above under Impact F-3. This impact is considered less than significant.

Mitigation. No mitigation is required.

Potential Flow and General Habitat Effects

Increased demands for water could increase fluctuation in Shasta Reservoir storage, which would adversely affect riverine conditions. Upstream conditions for fish (e.g., water temperature) may continue to deteriorate. Compliance with measures included in the CVP-OCAP winter-run biological opinion (NMFS 1993, 1995) would limit adverse effects on winter-run chinook salmon.

If DW project water is purchased by the CVP and the SWP and the DW project is integrated into CVP and SWP operations, upstream conditions could be affected. Water discharged from the DW reservoir islands to supplement Delta outflow or for CVP and SWP export may modify upstream releases from Shasta, Oroville, and Folsom Dams. In general, reservoir water could be stored for longer periods rather than being released to meet Delta flow needs.

Without specific criteria to reduce Delta habitat degradation (including entrainment losses), ongoing factors and future projects could reduce the survival and abundance of all the species included in this assessment. Ongoing and future actions intended to improve fishery conditions, however, have the potential to reduce Delta and upstream habitat degradation and, consequently, reverse the downward trend in abundance that has characterized the change in many fish populations for at least the last 20-30 years (Appendix F1, "Supplemental Information on the Affected Environment for Fisheries", and Appendix F2, "Biological Assessment: Impacts of the Delta Wetlands Project on Fish Species"). Ongoing and future actions may include:

- potential implementation of fish protection recommendations by the CALFED operations coordination group to avoid adverse effects of water project operations (includes integration with the existing biological opinions for winter-run chinook salmon and delta smelt [NMFS 1995, USFWS 1995]),
- implementation of Category III, "Non-Flow Factors", as specified in the Principles for Agreement on Bay-Delta Standards Between the State of California and the Federal Government (SWRCB 1995),
- reinitiation of consultation under the federal Endangered Species Act to address exceedance of incidental take, impacts on winter-run chinook salmon or delta smelt not previously considered, listing of new species or designation of critical habitat that may be affected by water project operations, and
- implementation of actions included in the Anadromous Fish Restoration Program under the CVPIA.

DW project operations depend on the availability of surplus flows. Under future conditions, surplus flows are likely to be less available than under existing conditions. Reduced availability of surplus flow could result from operations that reduce the frequency of spill from upstream reservoirs, reduction of Delta surplus flows because of buildout by senior water right holders, and changes in the criteria that define surplus flows relative to beneficial uses of water in the Delta (e.g., the ongoing SWRCB actions relative to the 1995 WQCP).

Cumulative Delta flow conditions and exports for the No-Project Alternative and Alternative 1 are presented in Tables 3A-12 through 3A-15 in Chapter 3A. DW project diversion patterns for Alternative 1 simulated for 1995 WQCP conditions (Table 3A-7 in Chapter 3A) were similar to the diversion patterns for cumulative conditions (Table 3A-15 in Chapter 3A). The major difference is that under cumulative conditions, less water would be available for DW to divert.

Patterns of DW discharge for export under Alternative 1 simulated for 1995 WQCP conditions (Table 3A-7 in Chapter 3A) were similar to the patterns of discharge for export for cumulative conditions (Table 3A-15 in Chapter 3A). For Alternative 1, discharge for export under cumulative conditions shifted to July and away from August and September. This occurred because of the assumed increased pumping rate of the SWP pumps and because the percent inflow standard is rarely limiting during July. The magnitude of discharge for export simulated during the other months, however, was similar because of the reduction in stored water available for discharge.

The effect of the DW project operations under cumulative future conditions would be similar to or less than the effects described previously in this assessment because less water would be available for DW to divert.

Potential Species-Specific Effects

Significant species-specific impacts and mitigation measures would be similar to those described under "Impacts and Mitigation Measures of Alternative 1" because flow and habitat effects of DW project operations would be similar.

Impact F-19: Potential Increase in the Mortality of Chinook Salmon Resulting from the Indirect Effects of Diversions and Discharges on Flows under Cumulative Conditions. This impact is described above under Impact F-4. This impact is considered significant. Implementing Mitigation Measure F-3 would reduce Impact F-19 to a less-than-significant level.

Mitigation Measure F-3: Operate the DW Project under Operations Objectives That Would Minimize Changes in Cross-Delta Flow Conditions during Peak Out-Migration of Mokelumne and San Joaquin River Chinook Salmon. This mitigation measure is described above under "Impacts and Mitigation Measures of Alternative 1".

Impact F-20: Reduction in Downstream Transport and Increase in Entrainment Loss of Striped Bass Eggs and Larvae, Delta Smelt Larvae, and Longfin Smelt Larvae under Cumulative Conditions. This impact is described above under Impact F-5. This impact is considered significant. Implementing Mitigation Measure F-4 would reduce Impact F-20 to a less-than-significant level.

Mitigation Measure F-4: Operate the DW Project under Operations Objectives That Would Minimize Adverse Transport Effects on Striped Bass, Delta Smelt, and Longfin Smelt. This mitigation measure is described above under "Impacts and Mitigation Measures of Alternative 1".

Impact F-21: Change in Area of Optimal Salinity Habitat under Cumulative Conditions. The impact is described above under Impact F-6. This impact is considered less than significant.

Mitigation. No mitigation is required.

Impact F-22: Increase in Entrainment Loss of Juvenile Striped Bass and Delta Smelt under Cumulative Conditions. This impact is described above under Impact F-7. This impact is considered significant. Implementing Mitigation Measure F-5 would reduce Impact F-22 to a less-than-significant level.

Mitigation Measure F-5: Operate the DW Project under Operations Objectives That Would Minimize Entrainment of Juvenile Striped Bass and Delta Smelt. This mitigation measure is described above under "Impacts and Mitigation Measures of Alternative 1".

Impact F-23: Increase in Entrainment Loss of Juvenile American Shad and Other Species under Cumulative Conditions. The impact is described above under Impact F-8. This impact is considered less than significant.

Mitigation. No mitigation is required.

Cumulative Impacts, Including Impacts of Alternative 2

Effects of Construction Activities

The cumulative effects of construction activities under Alternative 2 would be the same as the cumulative effects described for Alternative 1.

Effects on Water Quality

Under Alternative 2, cumulative effects of DW project operations on water quality would be the same as described for Alternative 1.

Potential Flow and General Habitat Effects

Potential flow and habitat effects under Alternative 2 are similar to effects described under Alternative 1. Cumulative Delta flow conditions and exports for the No-Project Alternative and Alternative 2 are presented in Tables 3A-12, 3A-13, 3A-16, and 3A-17 in Chapter 3A. DW project diversion patterns for Alternative 2 simulated for 1995 WQCP conditions (Table 3A-9 in Chapter 3A) were similar to the diversion patterns for cumulative conditions (Table 3A-17 in Chapter 3A). The major difference is that under cumulative conditions, less water would be available for DW to divert.

Patterns of DW discharge for export under Alternative 2 simulated for 1995 WQCP conditions (Table 3A-9 in Chapter 3A) were similar to the patterns of discharge for export for cumulative conditions (Table 3A-17 in Chapter 3A). For Alternative 2, simulated discharges for export for August and September were absent or reduced under cumulative conditions. DW stored water would be discharged and exported earlier because of the increased SWP pumping rate. The magnitude of discharge for export simulated during the other months, however, was similar because of the reduction in stored water available for discharge.

The effect of the DW project operations under cumulative future conditions would be similar to or less than the effects described previously in this assessment.

Potential Species-Specific Effects

Significant species-specific impacts and mitigation measures under Alternative 2 would be the same as described for Alternative 1.

Cumulative Impacts, Including Impacts of Alternative 3

Effects of Construction Activities

Effects of construction activities under Alternative 3 would be the same as described for Alternative 1.

Effects on Water Quality

Under Alternative 3, effects of DW project operations on water quality would be the same as described for Alternative 1.

Potential Flow and General Habitat Effects

Potential flow and habitat effects under Alternative 3 are similar to effects described under Alternative 1. Cumulative Delta flow conditions and exports for the No-Project Alternative and Alternative 3 are presented in Tables 3A-12, 3A-13, 3A-18, and 3A-19 in Chapter 3A. DW project diversion patterns for Alternative 3 simulated for 1995 WQCP conditions (Table 3A-11 in Chapter 3A) were similar to the diversion patterns for cumulative conditions (Table 3A-19 in Chapter 3A). The major difference is that under cumulative conditions, less water would be available for DW to divert. For Alternative 3, some diversion would shift to December and January when storm events are generally larger and water is available to meet both the increased diversions of the SWP and the CVP and diversions onto the DW reservoir islands.

Patterns of DW discharge for export under Alternative 3 simulated for 1995 WQCP conditions (Table 3A-11 in Chapter 3A) were similar to the patterns of discharge for export for cumulative conditions (Table 3A-19 in Chapter 3A). For Alternative 3, simulated discharges for export for August and September were absent or reduced under cumulative conditions. DW stored water would be discharged and exported earlier because of the increased SWP pumping rate. The magnitude of discharge for export simulated during the other months, however, was similar because of the reduction in stored water available for discharge.

The effect of the DW project operations under cumulative future conditions would be similar to or less than the effects described previously in this assessment.

Potential Species-Specific Effects

Significant species-specific impacts and mitigation measures under Alternative 3 would be the same as described for Alternative 1.

Cumulative Impacts, Including Impacts of the No-Project Alternative

Under the No-Project Alternative, consumptive use on the DW islands would not measurably increase above existing conditions (see Chapter 3A, "Water Supply and Water Project Operations"). DW operations under the No-Project Alternative would contribute minimally to cumulative impacts on fish species or habitat in the Delta.

CITATIONS

References to the Federal Register (FR) are not included in this list. FR citations in text refer to volume and page number (e.g., 58 FR 12854 refers to Volume 58 of the FR, page 12854).

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Table 3F-1. Average Change in Delta Outflow under DW Project Operations Relative to No-Project Conditions, 1922-1991 Simulation

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Change in Flow (cfs)												
Alternative 1												
Mean	(650)	(710)	(524)	(676)	(414)	(142)	30	31	57	35	50	(353)
Standard Deviation	1,261	1,396	1,141	1,286	1,095	745	56	63	35	45	26	1,102
Minimum	(3,880)	(4,011)	(3,892)	(3,856)	(3,977)	(3,797)	(141)	(236)	(49)	(52)	(55)	(3,974)
Median	(10)	(12)	(34)	0	(7)	25	51	60	69	78	60	25
Maximum	(10)	(12)	(21)	15	47	73	330	60	69	78	60	25
Alternative 2												
Mean	(650)	(710)	(524)	(644)	(414)	(163)	(38)	29	57	35	50	(353)
Standard Deviation	1,261	1,396	1,141	1,275	1,095	714	430	68	35	45	26	1,102
Minimum	(3,880)	(4,011)	(3,892)	(3,856)	(3,977)	(3,797)	(3,074)	(252)	(49)	(52)	(55)	(3,974)
Median	(10)	(12)	(34)	0	(7)	25	51	60	69	78	60	25
Maximum	(10)	(12)	(21)	15	47	73	330	60	69	78	60	25
Alternative 3												
Mean	(955)	(1,122)	(949)	(958)	(719)	(266)	(32)	46	107	70	97	(376)
Standard Deviation	1,771	2,063	1,832	1,785	1,683	927	419	112	71	84	48	1,337
Minimum	(5,959)	(5,970)	(5,985)	(5,982)	(5,959)	(5,945)	(2,926)	(383)	(104)	(110)	(115)	(5,931)
Median	41	30	(11)	(11)	(19)	(42)	74	101	131	150	116	69
Maximum	41	30	15	18	83	55	354	101	131	150	116	69
Change in Flow (%)												
Alternative 1												
Mean	(5.85)	(4.34)	(2.88)	(4.03)	(1.18)	(0.20)	0.33	0.47	0.79	0.56	1.02	(2.96)
Standard Deviation	11.13	8.71	6.02	7.72	3.48	2.09	0.32	0.45	0.41	0.70	0.55	10.38
Minimum	(34.36)	(34.07)	(27.82)	(27.32)	(16.65)	(11.76)	(0.32)	(0.94)	(0.19)	(0.56)	(0.64)	(39.06)
Median	(0.24)	(0.25)	(0.38)	0.00	(0.01)	0.10	0.35	0.54	0.91	0.87	1.05	0.66
Maximum	(0.16)	(0.05)	(0.02)	0.33	0.41	1.06	1.80	1.34	1.73	1.95	1.76	0.84
Alternative 2												
Mean	(5.85)	(4.34)	(2.88)	(3.89)	(1.18)	(0.28)	0.16	0.47	0.79	0.56	1.02	(2.96)
Standard Deviation	11.13	8.71	6.02	7.72	3.48	2.08	1.12	0.46	0.41	0.70	0.55	10.38
Minimum	(34.36)	(34.07)	(27.82)	(27.32)	(16.65)	(11.76)	(7.00)	(0.94)	(0.19)	(0.56)	(0.64)	(39.06)
Median	(0.24)	(0.25)	(0.38)	0.00	(0.01)	0.10	0.35	0.54	0.91	0.87	1.05	0.66
Maximum	(0.16)	(0.05)	(0.02)	0.33	0.41	1.06	1.80	1.34	1.73	1.95	1.76	0.84
Alternative 3												
Mean	(7.28)	(6.25)	(4.56)	(5.16)	(1.81)	(0.58)	0.29	0.78	1.51	1.12	1.98	(2.37)
Standard Deviation	14.06	11.65	9.22	9.63	4.70	2.50	1.15	0.76	0.79	1.32	1.03	11.94
Minimum	(42.19)	(39.07)	(39.35)	(33.31)	(19.87)	(13.89)	(6.66)	(1.05)	(0.41)	(1.19)	(1.34)	(44.36)
Median	0.81	0.47	(0.02)	(0.04)	(0.01)	(0.03)	0.51	0.90	1.73	1.68	2.01	1.81
Maximum	1.36	0.86	0.32	0.40	0.73	0.80	1.93	2.24	3.28	3.75	3.39	2.29

Note: Negative values shown in parentheses.

Table 3F-2. Average Change in X2 (Kilometers) under DW Project Operations Relative to No-Project Conditions, 1922-1991 Simulation

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Alternative 1												
Mean	0.62	0.57	0.42	0.48	0.26	0.11	0.03	0.00	(0.04)	(0.01)	(0.00)	0.33
Standard Deviation	1.05	0.82	0.56	0.66	0.33	0.19	0.06	0.03	0.04	0.01	0.01	0.96
Minimum	(0.00)	(0.00)	(0.00)	(0.02)	(0.03)	(0.09)	(0.05)	(0.07)	(0.13)	(0.04)	(0.01)	(0.00)
Median	0.00	0.01	0.22	0.17	0.09	0.03	0.01	0.00	(0.04)	(0.01)	(0.00)	(0.00)
Maximum	3.23	3.19	2.50	2.45	1.39	0.95	0.29	0.12	0.03	0.05	0.05	3.80
Alternative 2												
Mean	0.62	0.57	0.42	0.47	0.25	0.11	0.04	0.01	(0.04)	(0.01)	(0.00)	0.33
Standard Deviation	1.05	0.82	0.56	0.66	0.33	0.18	0.10	0.04	0.04	0.01	0.01	0.96
Minimum	(0.00)	(0.00)	(0.00)	(0.02)	(0.03)	(0.09)	(0.05)	(0.07)	(0.13)	(0.04)	(0.01)	(0.00)
Median	0.00	0.01	0.22	0.15	0.09	0.03	0.01	0.00	(0.03)	(0.01)	(0.00)	(0.00)
Maximum	3.23	3.19	2.50	2.45	1.39	0.95	0.56	0.18	0.06	0.05	0.05	3.80
Alternative 3												
Mean	0.86	0.87	0.69	0.68	0.38	0.17	0.06	0.01	(0.07)	(0.02)	(0.00)	0.38
Standard Deviation	1.41	1.16	0.93	0.86	0.46	0.24	0.11	0.05	0.07	0.03	0.02	1.10
Minimum	(0.07)	(0.02)	(0.01)	(0.02)	(0.05)	(0.08)	(0.05)	(0.11)	(0.25)	(0.08)	(0.03)	(0.01)
Median	(0.00)	0.00	0.37	0.26	0.17	0.07	0.03	0.01	(0.07)	(0.02)	(0.00)	(0.00)
Maximum	4.27	3.80	3.83	3.13	1.98	1.13	0.54	0.18	0.06	0.10	0.11	4.50

Note: Negative values shown in parentheses.

Table 3F-3. Average Change in Net Flow (cfs) in Old and Middle Rivers near the Northern Confluence with the San Joaquin River under DW Project Operations Relative to No-Project Conditions, 1922-1991 Simulation

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Alternative 1												
Mean	(0)	(12)	(215)	(39)	(181)	(78)	(200)	(259)	(130)	(910)	(796)	(304)
Standard Deviation	0	67	692	321	776	422	374	431	383	1,362	1,096	775
Minimum	(0)	(515)	(3,335)	(2,708)	(4,000)	(2,691)	(1,332)	(1,843)	(2,822)	(3,741)	(3,755)	(3,379)
Median	0	0	0	0	0	0	0	0	0	0	0	0
Maximum	0	0	0	0	0	0	280	0	0	0	0	0
Alternative 2												
Mean	(0)	(12)	(176)	(54)	(674)	(437)	(77)	(283)	(783)	(497)	(293)	(79)
Standard Deviation	0	67	644	335	1,312	1,006	204	613	1,306	1,100	785	424
Minimum	(0)	(515)	(3,335)	(2,721)	(4,486)	(3,822)	(1,053)	(3,771)	(3,780)	(3,741)	(3,755)	(2,861)
Median	0	0	0	0	0	0	0	0	0	0	0	0
Maximum	0	0	0	0	0	0	280	0	0	0	0	0
Alternative 3												
Mean	(6)	(10)	(179)	(58)	(792)	(678)	(87)	(270)	(1,187)	(777)	(777)	(191)
Standard Deviation	50	60	669	336	1,581	1,277	225	546	1,844	1,587	1,415	644
Minimum	(425)	(473)	(3,740)	(2,717)	(6,000)	(4,975)	(1,030)	(3,000)	(4,899)	(6,000)	(5,237)	(3,917)
Median	0	0	0	0	0	0	0	0	0	0	0	0
Maximum	0	0	0	0	0	0	280	0	0	0	0	0

Note: Negative values shown in parentheses.
DW discharges and diversions are added to the Old and Middle River flow regardless of actual DW discharge and diversion locations.

Table 3F-4. Total Annual Mortality Index for Sacramento River Chinook Salmon, 70-Year Simulation Summary

	Mortality Index (%)				Change from No-Project Mortality Index (%)		
	No-Project	Alternative 1	Alternative 2	Alternative 3	Alternative 1	Alternative 2	Alternative 3
Fall-Run Chinook Salmon							
Mean	47.65	47.68	47.69	47.70	0.03	0.04	0.05
Standard Deviation	15.94	15.95	15.93	15.92	0.04	0.06	0.07
Minimum	13.91	13.91	13.91	13.91	-0.02	-0.02	-0.04
Median	50.41	50.42	50.48	50.51	0.02	0.02	0.04
Maximum	74.87	74.85	74.85	74.84	0.20	0.32	0.33
Winter-Run Chinook Salmon							
Mean	11.71	11.80	11.83	11.90	0.08	0.12	0.18
Standard Deviation	2.80	2.80	2.83	2.84	0.10	0.12	0.17
Minimum	6.21	6.25	6.25	6.32	-0.02	-0.02	-0.01
Median	12.44	12.58	12.76	12.79	0.05	0.06	0.12
Maximum	16.52	16.57	16.58	16.72	0.43	0.46	0.74

Note: The values do not account for any incremental benefits of DW fish screens.

The maximum and minimum changes are the largest and smallest differences between the values simulated for the same year for the No-Project Alternative and the specified DW project alternative. They cannot be calculated from the maximum and minimum index values.

C-060707

Table 3F-5. Total Annual Entrainment Index for Striped Bass, Delta Smelt, and Longfin Smelt; 70-Year Simulation Summary

	Entrainment Index (%)				Change from No-Project Entrainment Index (%)		
	No-Project	Alternative 1	Alternative 2	Alternative 3	Alternative 1	Alternative 2	Alternative 3
Striped Bass							
Mean	25.95	26.38	26.32	26.43	0.43	0.38	0.48
Standard Deviation	5.36	5.47	5.45	5.43	0.45	0.39	0.45
Minimum	1.24	1.28	1.28	1.32	-0.02	-0.23	-0.02
Median	27.80	28.01	28.08	28.24	0.24	0.26	0.43
Maximum	30.52	30.54	30.87	30.86	1.52	1.59	1.75
Delta Smelt							
Mean	26.79	27.41	27.58	27.89	0.62	0.80	1.10
Standard Deviation	6.03	6.29	6.37	6.41	0.75	0.84	1.05
Minimum	0.74	0.78	0.78	0.81	-0.02	-0.00	-0.00
Median	28.47	28.80	28.86	29.43	0.25	0.48	0.65
Maximum	34.46	36.29	36.16	36.15	3.22	3.44	4.15
Longfin Smelt							
Mean	8.26	9.10	9.33	9.73	0.84	1.07	1.47
Standard Deviation	4.40	4.95	5.15	5.38	1.24	1.40	1.84
Minimum	0.01	0.01	0.01	0.01	-0.00	-0.00	-0.00
Median	8.26	9.24	9.24	9.62	0.18	0.64	0.98
Maximum	18.65	20.95	21.71	21.70	5.66	6.42	9.31

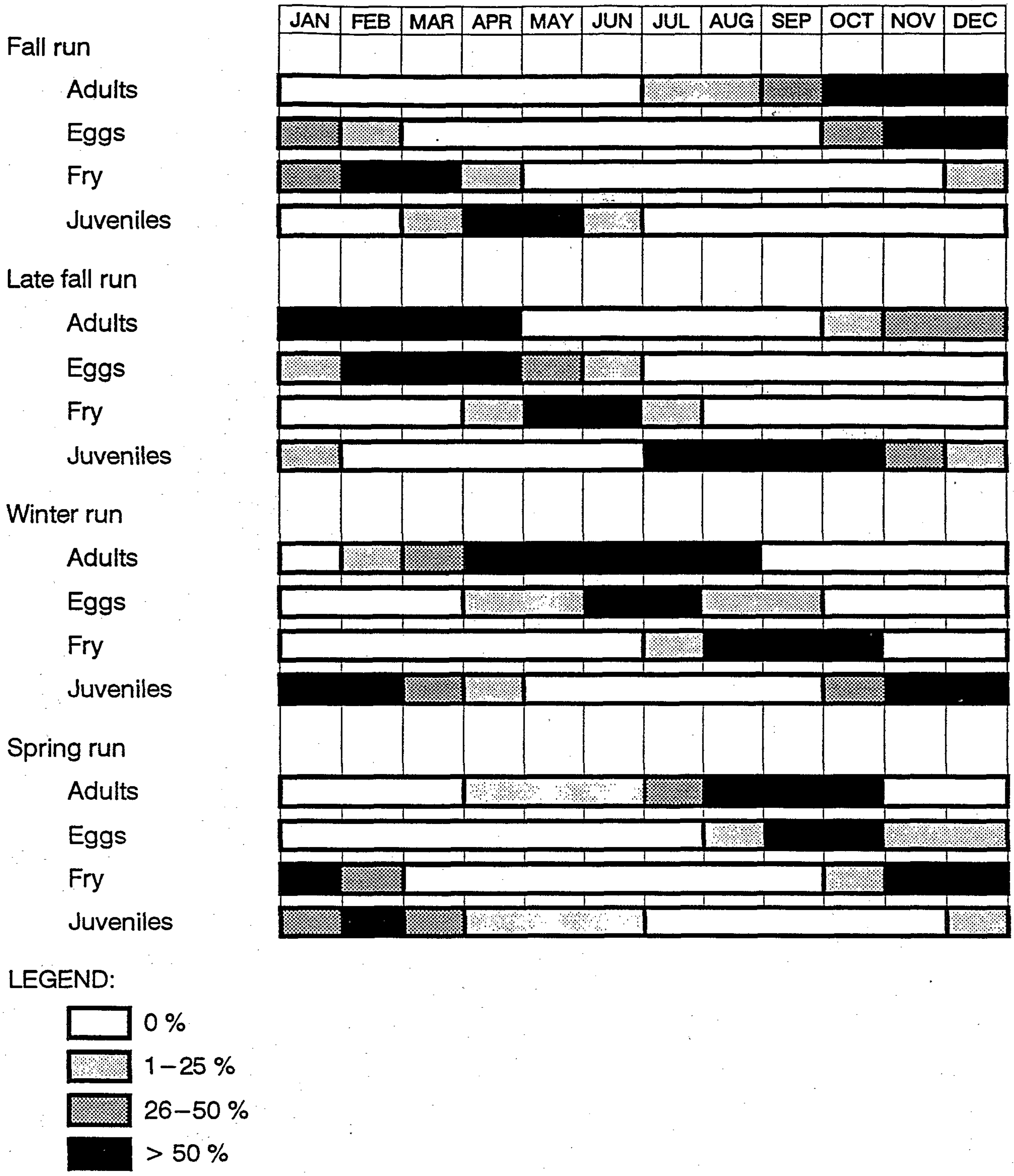
Note: The maximum and minimum changes are the largest and smallest differences between the values simulated for the same year for the No-Project Alternative and the specified DW project alternative. They cannot be calculated from the maximum and minimum index values.

Table 3F-6. Total Habitat Area for Striped Bass, Delta Smelt, and Longfin Smelt; 70-Year Simulation Summary

	Habitat Area (km^2)				Change from No-Project Habitat Area (km^2)		
	No-Project	Alternative 1	Alternative 2	Alternative 3	Alternative 1	Alternative 2	Alternative 3
Striped Bass							
Mean	76.53	76.71	76.70	76.76	0.18	0.16	0.23
Standard Deviation	14.93	14.94	14.92	14.91	0.60	0.61	0.72
Minimum	51.47	51.47	51.47	51.50	−1.82	−1.82	−1.82
Median	76.84	76.84	76.84	76.84	0.00	0.00	0.00
Maximum	101.82	101.82	101.82	101.82	2.86	2.86	2.86
Delta Smelt							
Mean	50.70	50.75	50.75	50.74	0.05	0.05	0.04
Standard Deviation	4.67	4.60	4.60	4.58	0.37	0.40	0.59
Minimum	41.48	41.48	41.48	41.48	−0.91	−1.11	−1.61
Median	49.26	49.70	49.65	49.70	0.00	0.00	0.00
Maximum	67.55	67.49	67.49	67.49	1.05	1.05	2.36
Longfin Smelt							
Mean	173.58	172.71	172.66	172.69	−0.87	−0.93	−0.90
Standard Deviation	34.70	34.82	34.81	34.75	2.34	2.35	2.67
Minimum	122.21	122.03	122.03	122.03	−7.29	−7.29	−12.55
Median	173.70	172.37	172.37	173.63	0.00	0.00	0.00
Maximum	248.22	248.22	248.22	248.22	3.04	1.99	2.54

Note: The maximum and minimum changes are the largest and smallest differences between the values simulated for the same year for the No-Project Alternative and the specified DW project alternative. They cannot be calculated from the maximum and minimum index values.

C-060709



Note: Adults are represented as percentage of spawning population that has arrived on the spawning grounds. Designations for other life stages represent the percentage of year's brood.

Figure 3F-1.
Occurrence of Chinook Salmon by Life Stage in the Sacramento River Basin

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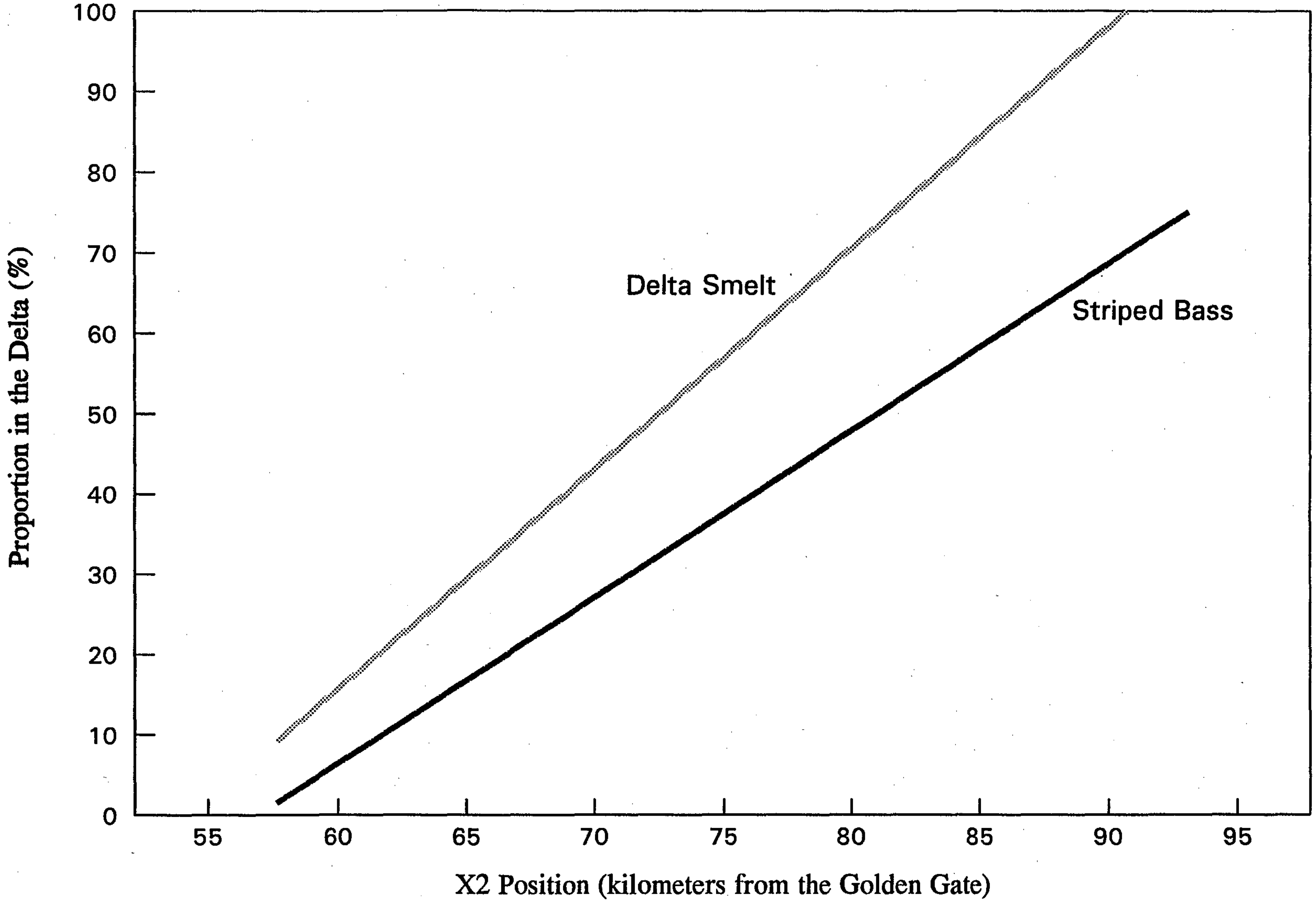
Prepared by: Jones & Stokes Associates



Source: DFG 1992b, 1992c.

Figure 3F-2.
Relationship between the Location of X2 and the Proportion of the Delta Smelt and Striped Bass Populations in the Delta

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Prepared by: Jones & Stokes Associates

C-060711

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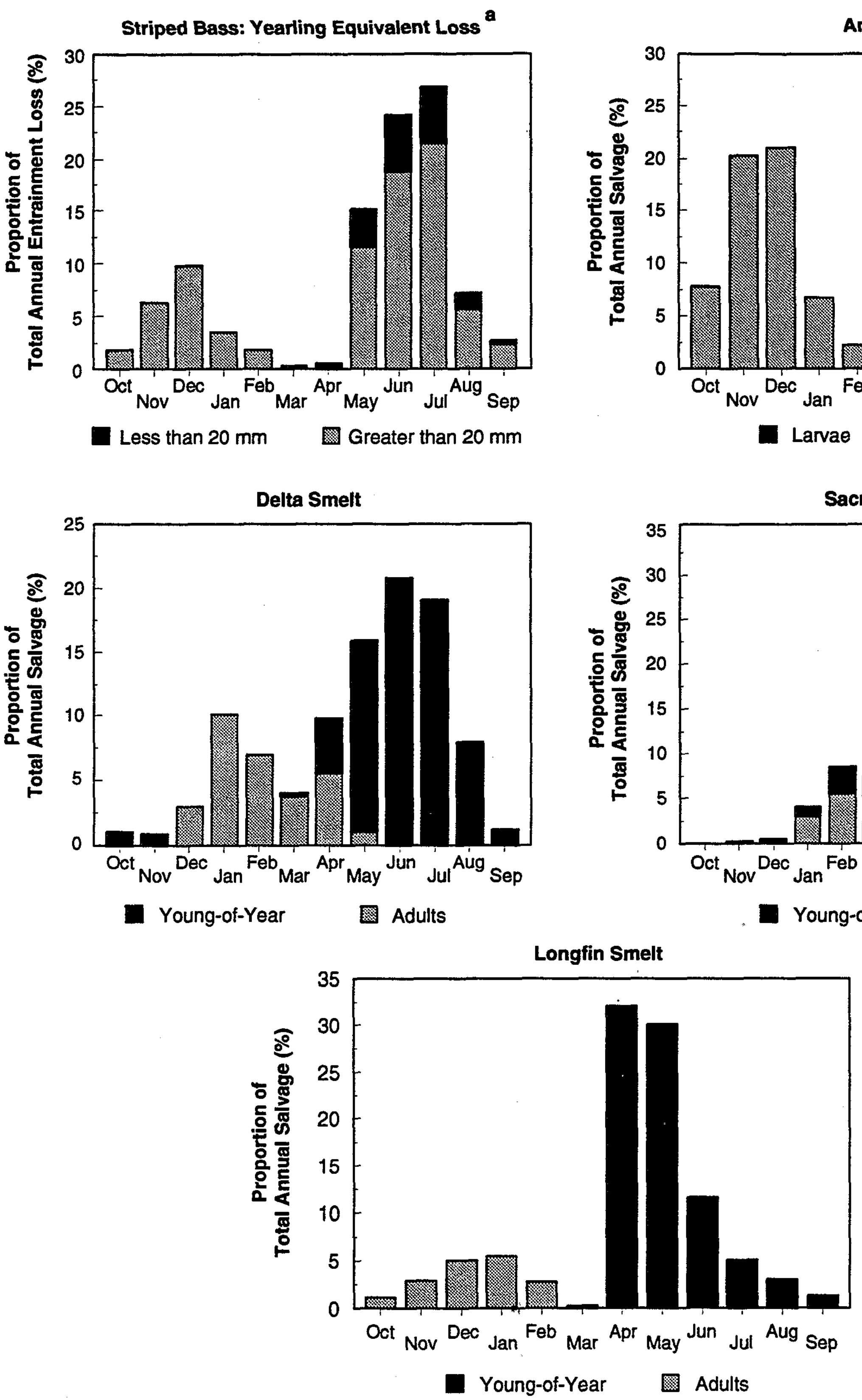

[a] Yearling equivalent loss is calculated by converting actual losses of a given age group to the number that would have remained at 1 year of age after natural mortality.

Figure 3F-3.
Monthly Distribution of Entrainment Loss of Striped Bass and Salvage of American Shad, Delta Smelt, Sacramento Splittail, and Longfin Smelt at the SWP and CVP Fish Protection Facilities, 1979–1990

DELTA WETLANDS
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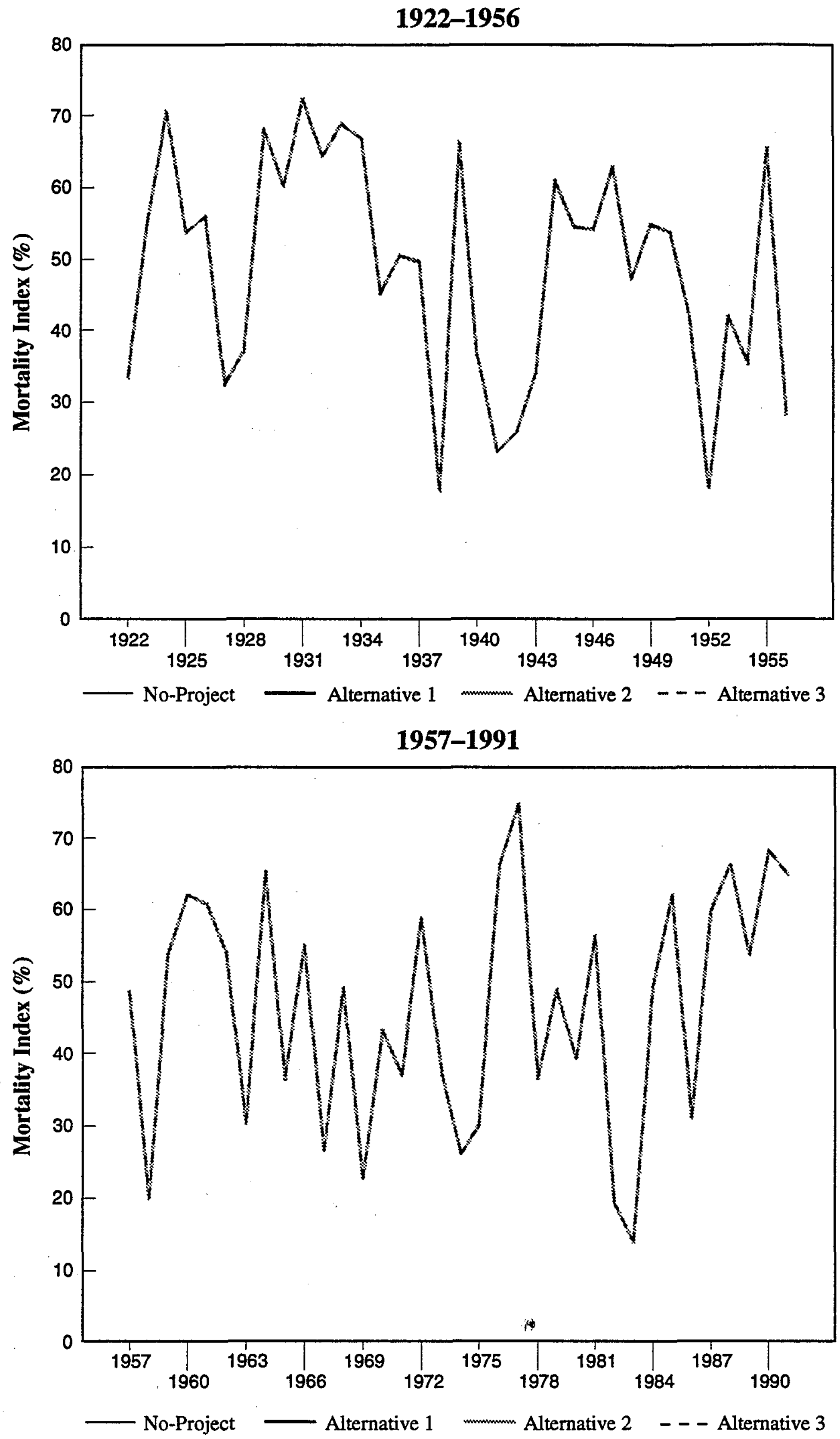
Prepared by: Jones & Stokes Associates



Note: Where results appear to be represented by a single line, little difference exists between the alternatives.

Figure 3F-4.
Total Mortality Index for Fall-Run Chinook Salmon from the Sacramento River during Juvenile Migration through the Delta, 1922–1991 Simulation

DELTA WETLANDS
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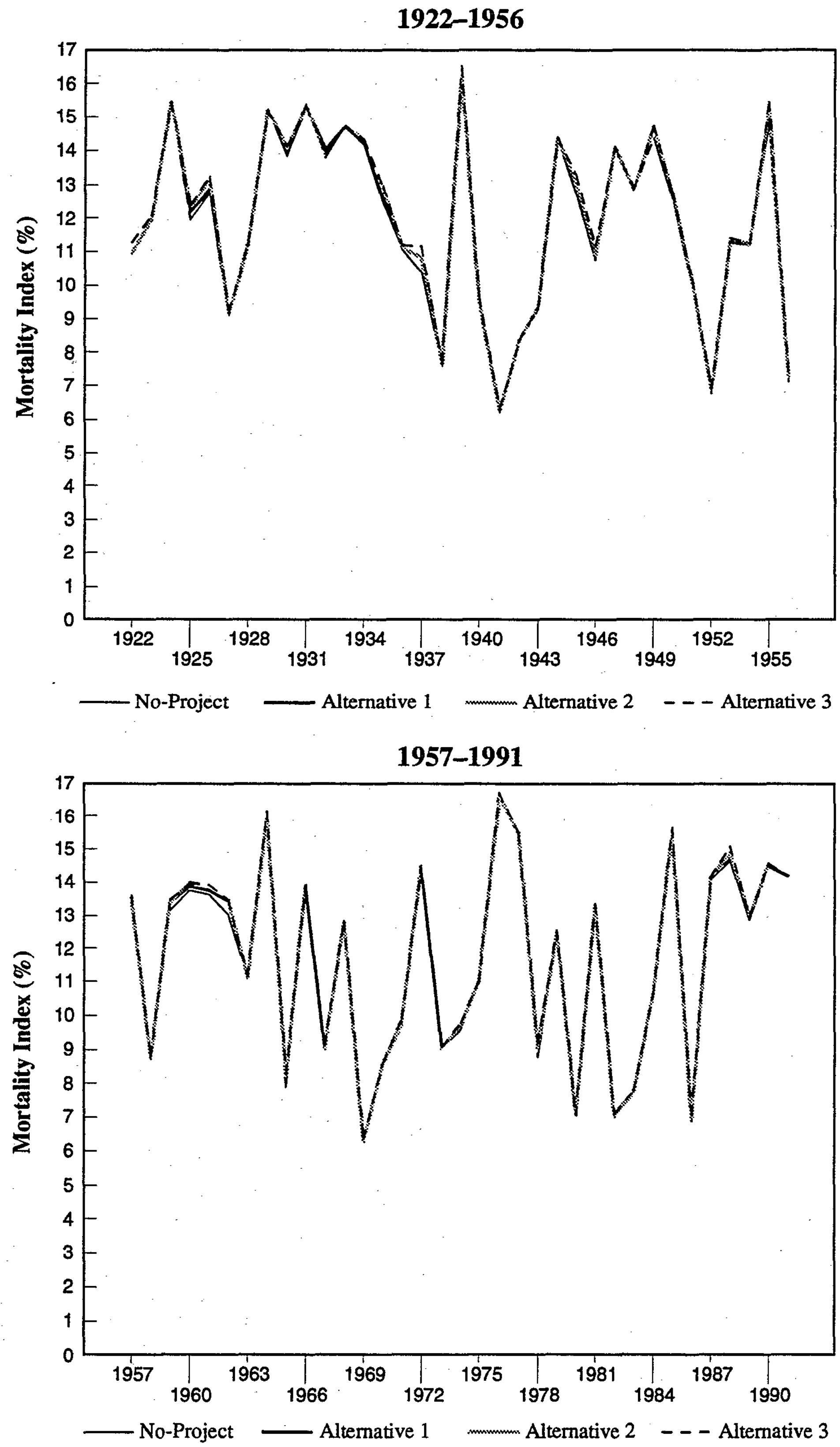
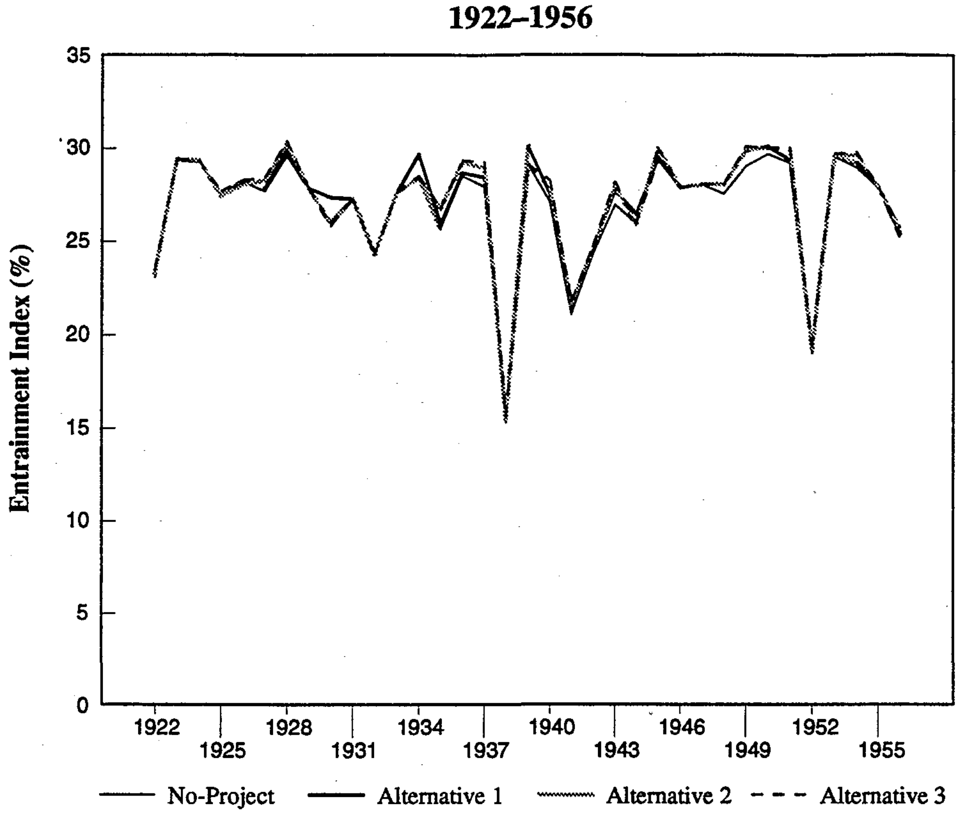
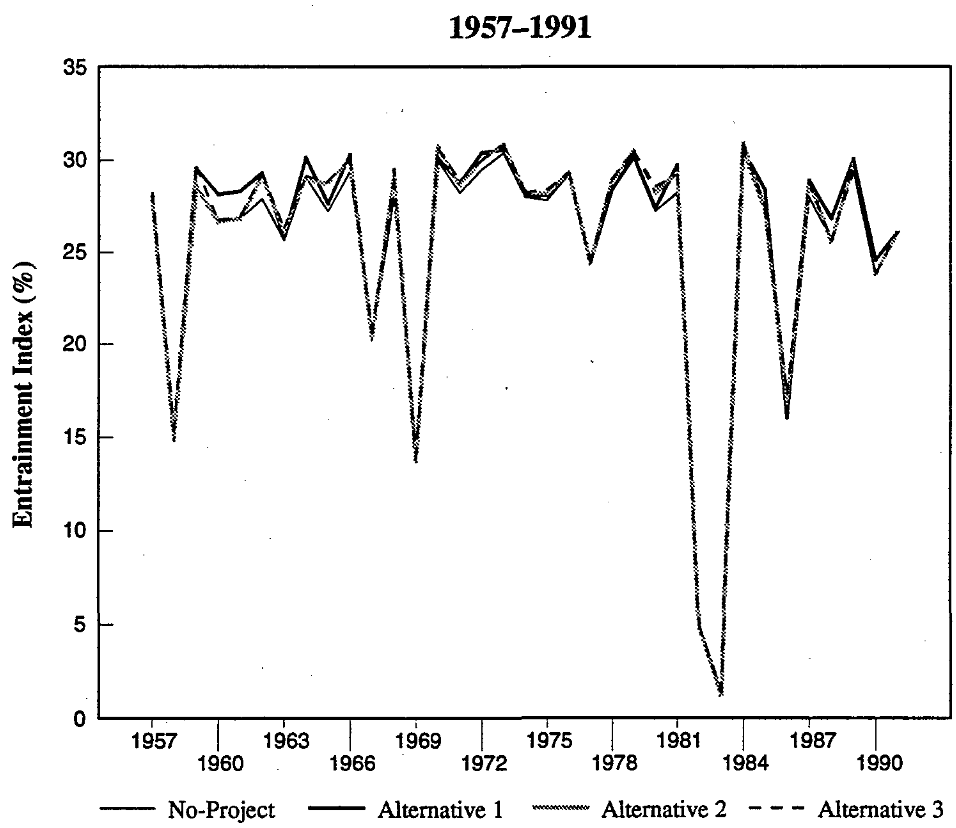
Prepared by: Jones & Stokes Associates



Note: Where results appear to be represented by a single line, little difference exists between the alternatives.

Figure 3F-5.
Total Mortality Index for Winter-Run Chinook Salmon from the Sacramento River during Juvenile Migration through the Delta, 1922–1991 Simulation

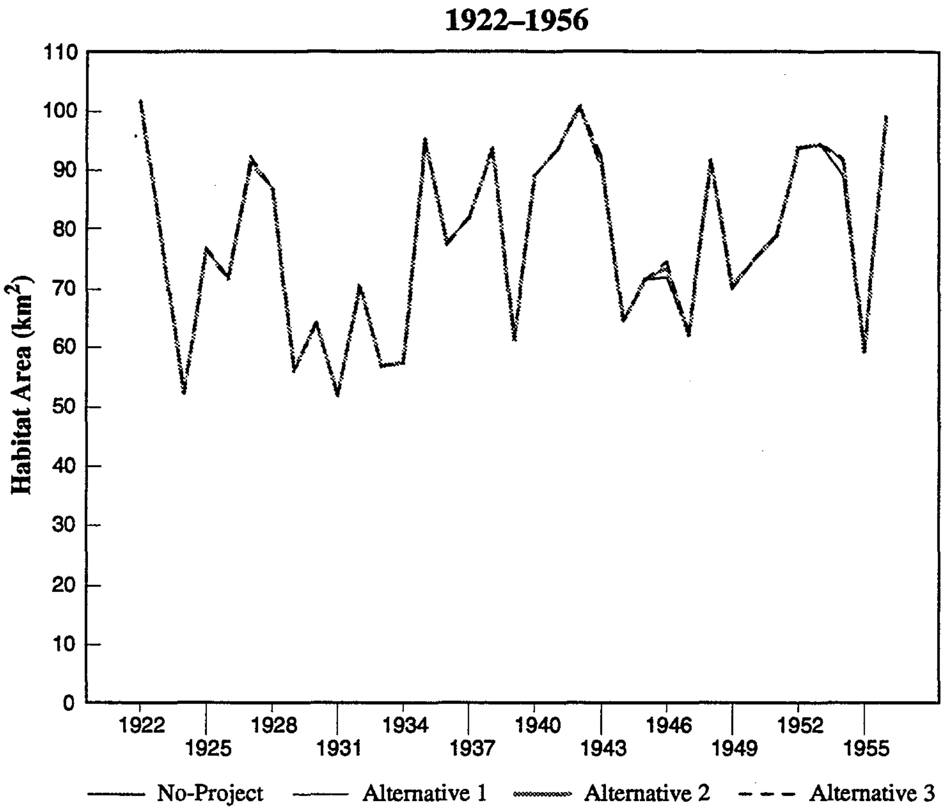


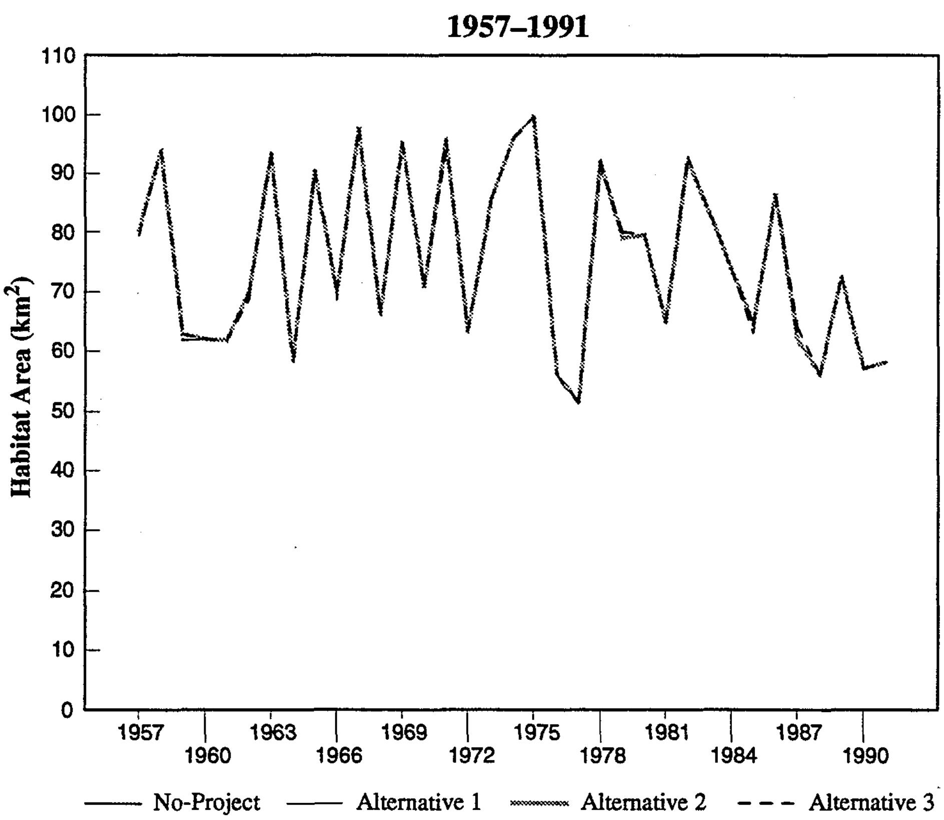


Note: Where results appear to be represented by a single line, little difference exists between the alternatives.

Figure 3F-6.
Total Entrainment Index for Striped Bass Eggs and Larvae Entrained in All Delta Diversions, 1922–1991 Simulation

DELTA WETLANDS
PROJECT EIR/EIS
Prepared by: Jones & Stokes Associates





Note: Where results appear to be represented by a single line, little difference exists between the alternatives.

Figure 3F-7.
Estuarine Habitat Area for Striped Bass, 1922–1991 Simulation

DELTA WETLANDS
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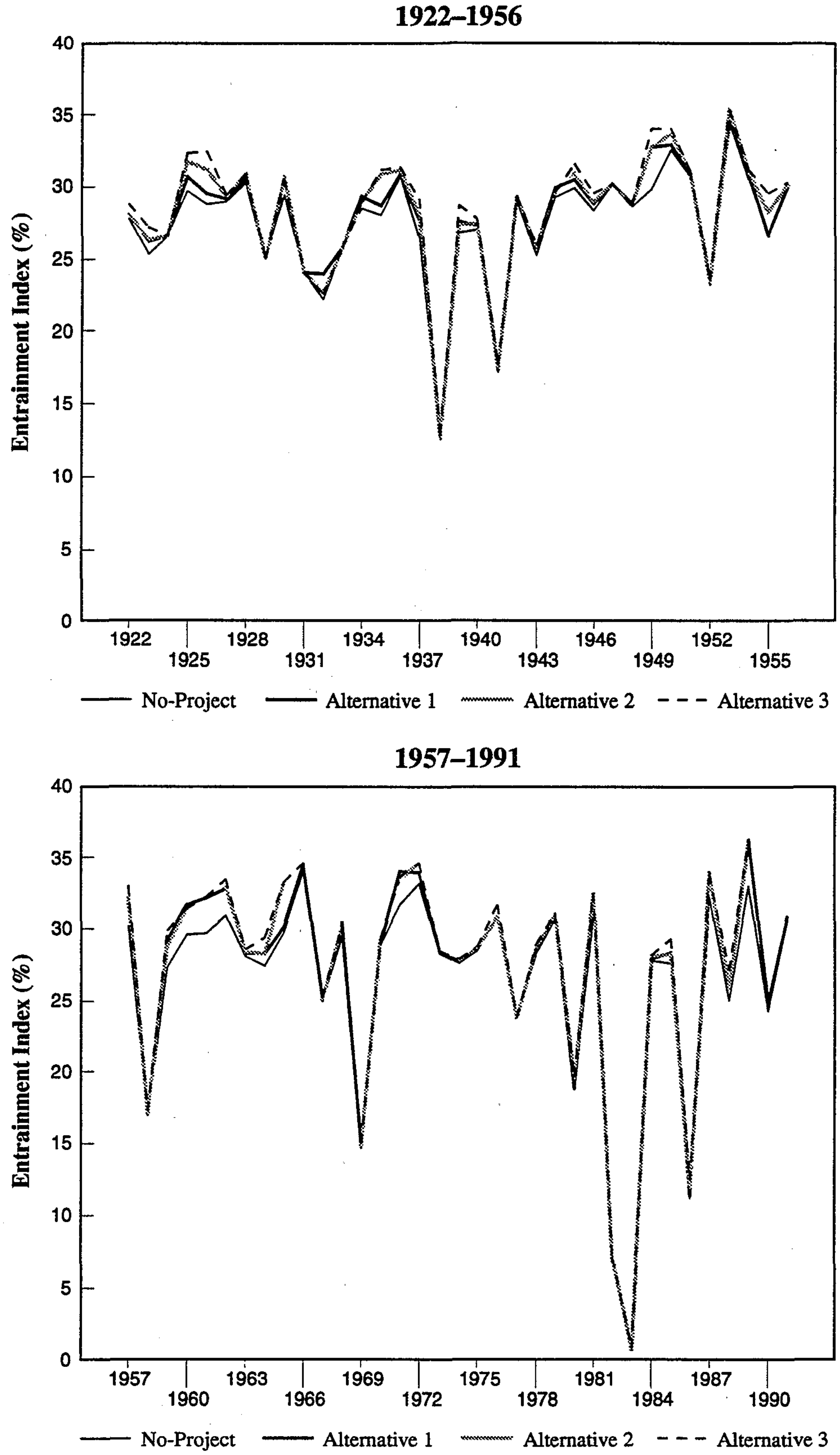
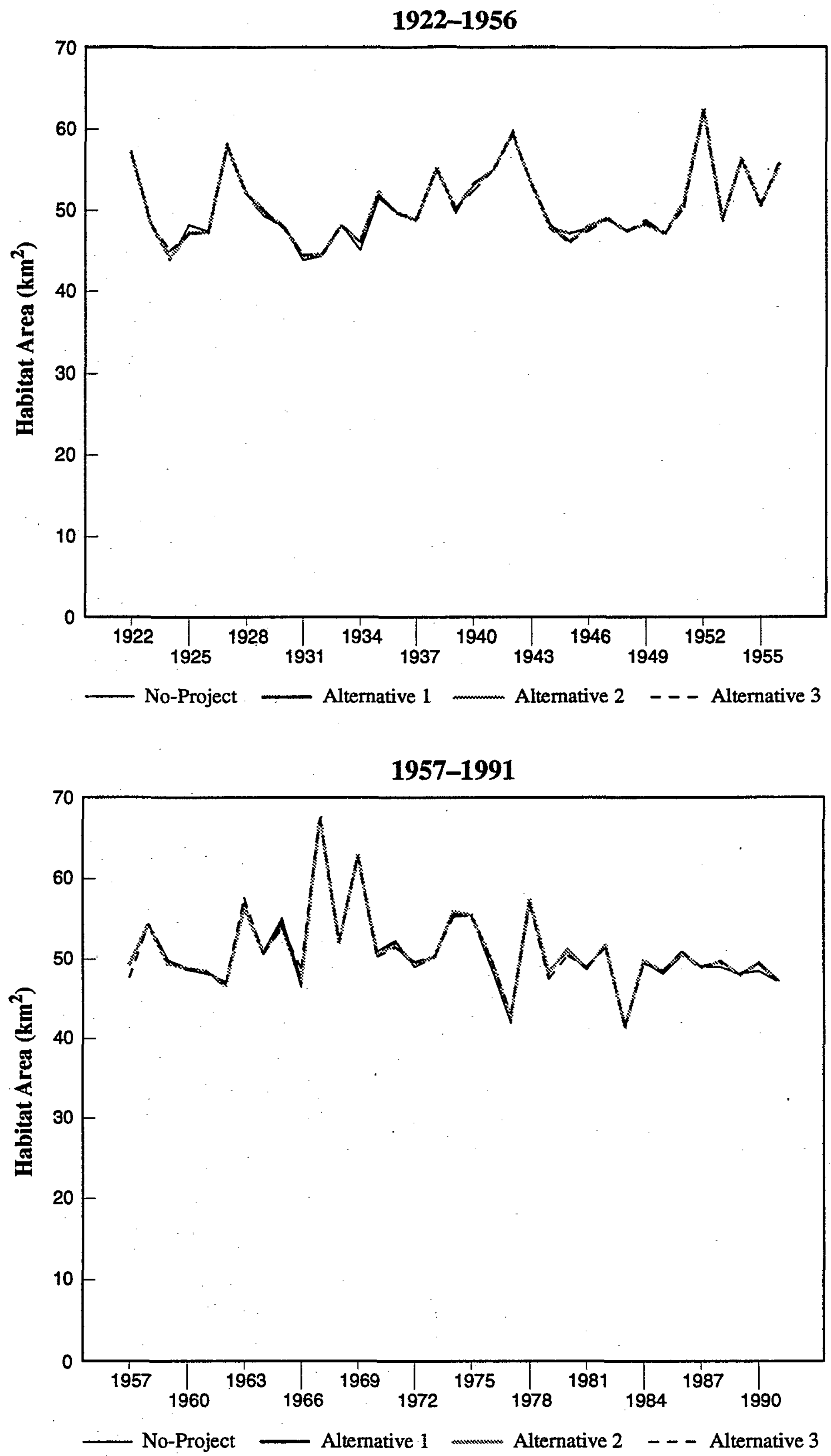
Prepared by: Jones & Stokes Associates



Note: Where results appear to be represented by a single line, little difference exists between the alternatives.

Figure 3F-8.
Total Entrainment Index for Delta Smelt Larvae Entrained in All Delta Diversions, 1922–1991 Simulation

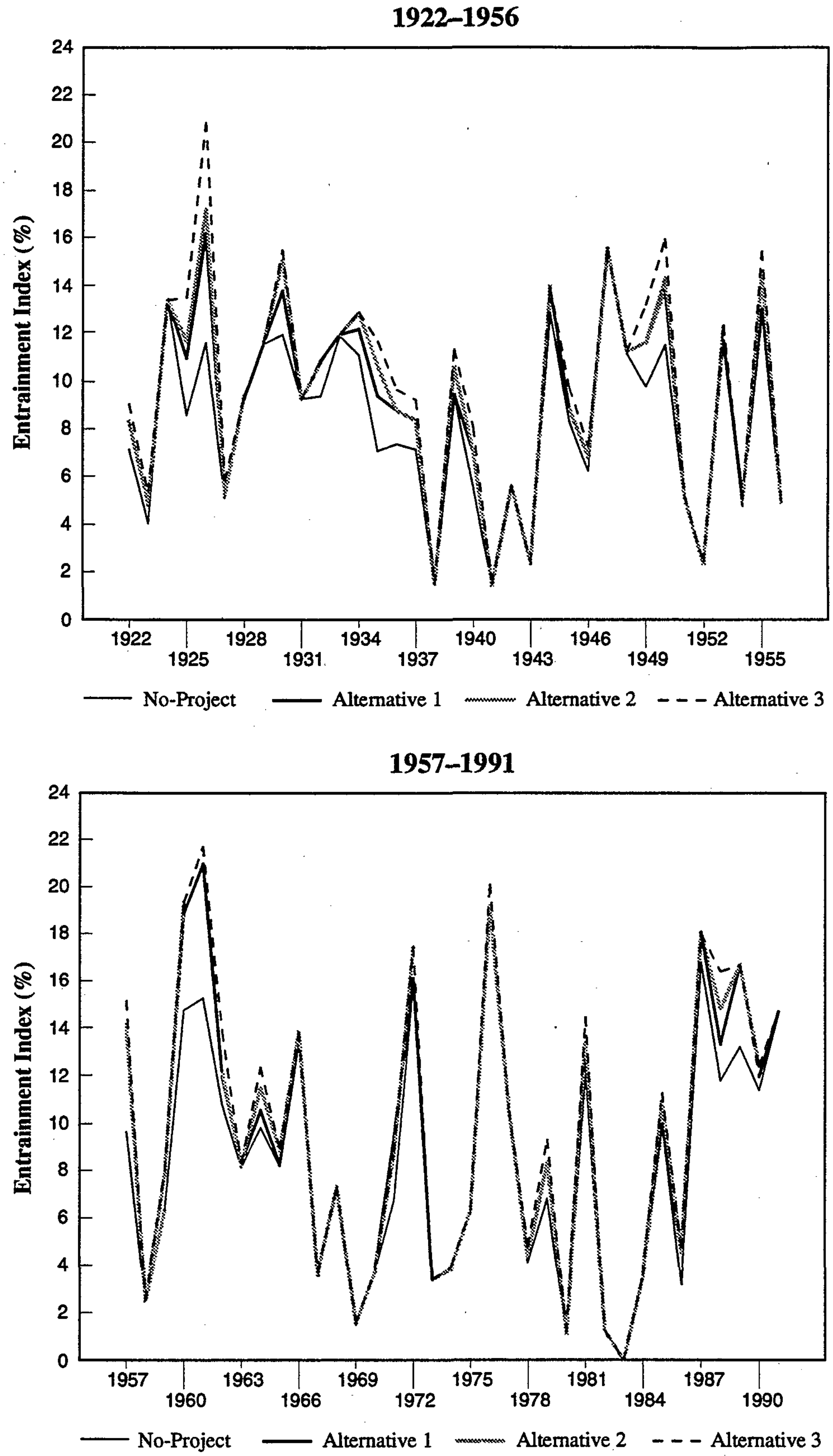
DELTA WETLANDS
PROJECT EIR/EIS
Prepared by: Jones & Stokes Associates



Note: Where results appear to be represented by a single line, little difference exists between the alternatives.

Figure 3F-9.
Estuarine Habitat Area for Delta Smelt, 1922–1991 Simulation

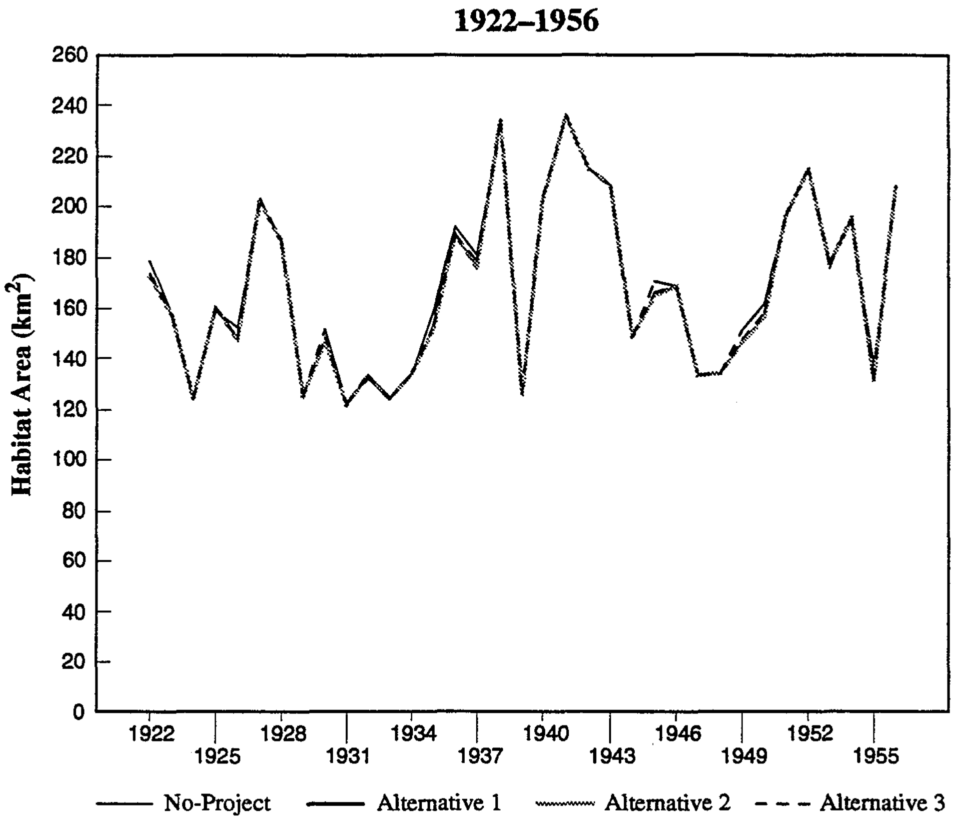
DELTA WETLANDS
PROJECT EIR/EIS
Prepared by: Jones & Stokes Associates

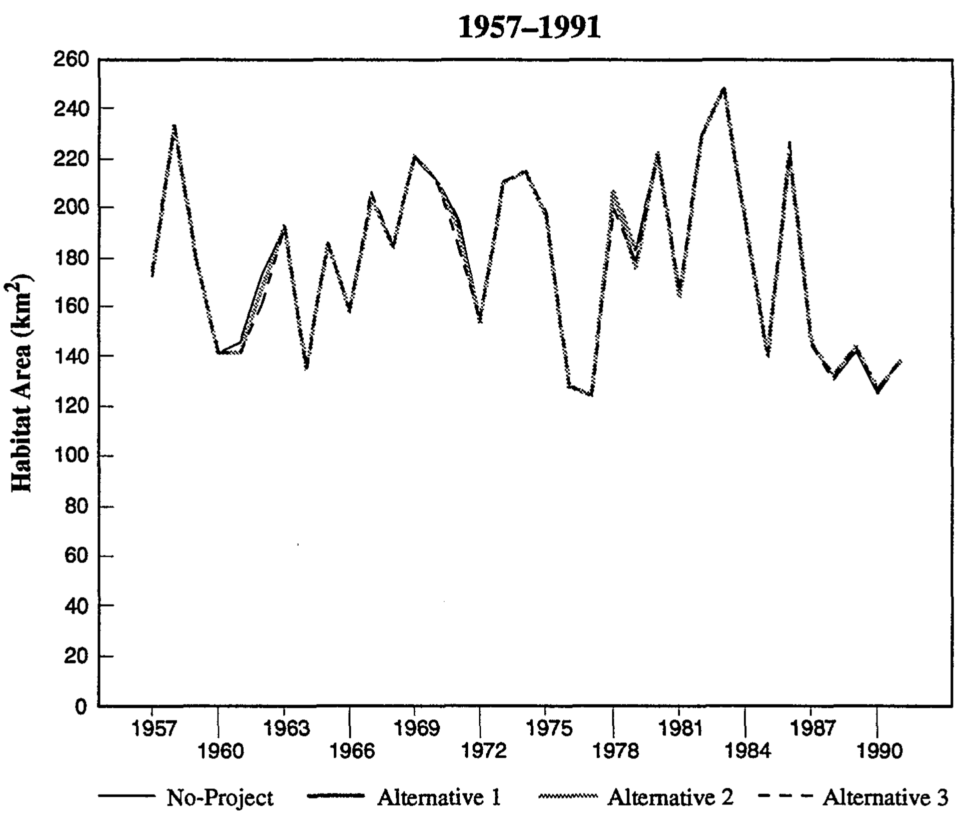


Note: Where results appear to be represented by a single line, little difference exists between the alternatives.

Figure 3F-10.
Total Entrainment Index for Longfin Smelt Larvae Entrained in All Delta Diversions, 1922–1991 Simulation

DELTA WETLANDS
PROJECT EIR/EIS
Prepared by: Jones & Stokes Associates





Note: Where results appear to be represented by a single line, little difference exists between the alternatives.

Figure 3F-11.
Estuarine Habitat Area for Longfin Smelt, 1922–1991 Simulation

DELTA WETLANDS
PROJECT EIR/EIS
Prepared by: Jones & Stokes Associates